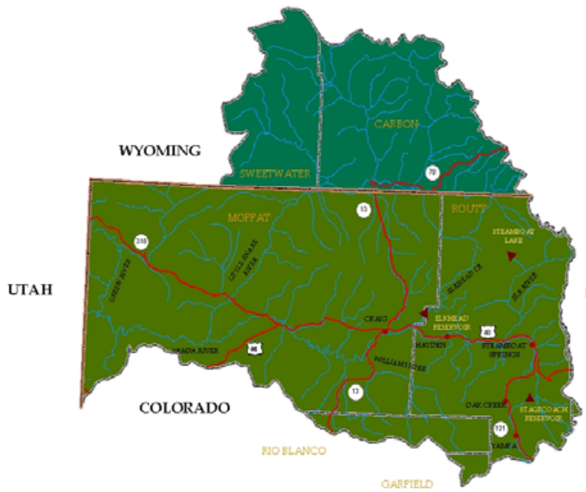
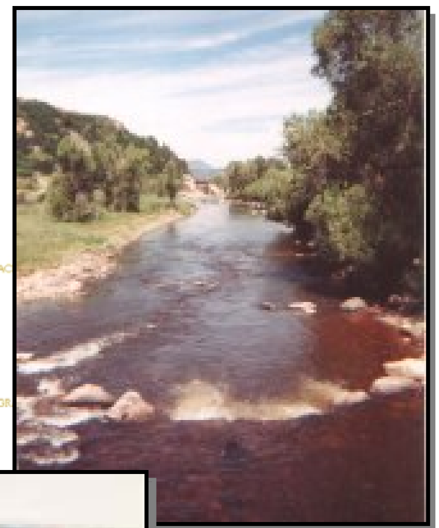
Yampa River Basin
Water Resources Planning Model
User's Manual





October 2009

COLORADO'S DECISION SUPPORT SYSTEMS

AECOM

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1. Introduction

1.1 Background

The Colorado Decision Support System (CDSS) consists of a database of hydrologic and administrative information related to water use in Colorado, and a variety of tools and models for reviewing, reporting, and analyzing the data. The CDSS water resources planning models, of which the Yampa River Basin Water Resources Planning Model (Yampa model) is one, are water allocation models which determine availability of water to individual users and projects, based on hydrology, water rights, and operating rules and practices. They are implementations of "StateMod", a code developed by the State of Colorado for application in the CDSS project. The Yampa model "Baseline" data set, which this document describes, extends from the most currently available hydrologic year back to 1909. It simulates current demands, current infrastructure and projects, and the current administrative environment, as though they had been in place throughout the modeled period.

The Yampa model was developed as a tool for investigators and decision makers to test impacts and efficacy of proposed structures, operations, or management strategies under complex administrative constraints and highly variable physical water supply. The Baseline data set can serve as the starting point for such analysis, demonstrating condition of the stream absent the proposed change but including all current conditions. It is presumed that the user will compare the Baseline simulation results to results from a model to which he has added the proposed features, to determine their performance and effects.

1.2 Development of the Yampa River Basin Water Resources Planning Model

The Yampa model was developed in a series of phases that spanned 1994 through the present. The earliest effort, designated Phase II following a Phase I scoping task, accomplished development of a calibrated model that simulated an estimated 75 percent of water use in the basin, leaving the remaining 25 percent of the use "in the gage". The original model study period was 1975 through 1991, which also served as the model's calibration period.

One objective of the CDSS endeavor was to represent all potential consumptive use within Colorado, and estimate actual consumptive use under water supply limitations. Thus in Phase IIIa, the heretofore unmodeled 25 percent use was added to the model as 27 aggregations of numerous small users. With the introduction of this demand, the calibration was reviewed and refined. The objective of Phase IIIb was to extend the model study period, using automated data filling techniques as well as "old-fashioned" research in the State's Records office to estimate or obtain historical gage and diversion information. The data set was extended back to 1909, and since the data were by then available, forward through 1996. The calibration was again reviewed, now using through the period 1975 through 1996.

The State continues to refine the Yampa basin model, creating a daily version in 2002, and more recently adding the "variable efficiency" method for determining irrigation consumptive use and return flows to the model. In 2004, the State modified representation of the upper Little Snake River basin in

Wyoming, drawing from Wyoming's Green River Basin Plan (GRBP) for irrigated acreage mapping and aggregation, crop demand, irrigation water requirement, efficiencies, and historical municipal depletions. The model was most recently updated in 2009 as part of the Colorado River Water Availability Study. The update included refining the approach to representing irrigation water requirement at high elevation, and incorporated changes in water rights and operations that have occurred since 2004.

1.3 Acknowledgements

CDSS is a project of the Colorado Water Conservation Board (CWCB), with support from the Colorado Division of Water Resources. The Yampa model has been developed and enhanced at different stages by Riverside Technology, Inc., Leonard Rice Engineers, AECOM (formerly Boyle Engineering Corporation), and CWCB staff.

The GRBP is a component of Wyoming's State Water Plan, and may be viewed at http://waterplan.state.wy.us/plan/green/green-plan.html. It was developed by States West Water Resources Corporation with assistance from Boyle Engineering Corporation, Purcell Consulting, Water Right Services, and Watts and Associates, Inc.

2. What's in This Document

2.1 Scope of this Manual

This reference manual describes the CDSS Yampa River Water Resources Planning Model, an application of the generic water allocation model StateMod and one component of the Colorado Decision Support System. It is intended for the reader who:

- Wants to understand basin operations and issues through review of the model
- Needs to evaluate the model's applicability to a particular planning or management issue
- Intends to use the model to analyze a particular Yampa River development or management scenario
- Is interested in estimated conditions on the Yampa River under current development, over a range of hydrologic conditions, as simulated by this model; and in understanding assumptions embedded in the modeling estimates.

Presumably, the reader has access to a complete set of data files for the Yampa model, as well as other CDSS documentation as needed (see below).

The manual describes content and assumptions in the model, implementation issues encountered, approaches used to estimate parameters, and results of both calibrating and simulating with the model. Only very general information is provided on the mechanics of assembling data sets, using various CDSS tools.

2.2 Manual Contents

Specifically, the manual is divided into the following sections:

Section 3 Yampa River Basin – describes the physical setting for the model, reviews very generally water resources development and issues in the basin.

Section 4 Modeling Approach – this is an overview of methods and techniques used in the Yampa model, addressing an array of typical modeling issues such as:

- aerial extent and spatial detail, including the model network diagram
- study period
- aggregation of small structures
- data filling methods

- simulation of processes related to irrigation use, such as delivery loss, soil moisture storage, crop consumptive use, and returns of excess diversions

- development of baseflows

- calibration methods

Much of Section 4 is common to the other CDSS West Slope models and the Rio Grande model, although the section refers specifically to the Yampa model.

Section 5 Baseline Data Set – the Baseline data set refers to the input files for simulating under current demands, current infrastructure and projects, and the current administrative environment, as though they were in place throughout the modeled period. The data set is generic with respect to future projects, and could be used as the basis against which to compare a simulation that includes a new use or operation. The user is advised, before appropriating the data set, to become fully aware of how demands and operations in particular are represented. Elements of these are subject to interpretation, and could legitimately be represented differently.

This section is organized by input file. The first is the response file, which lists all other files and therefore serves as a table of contents within the section. The content, source of data, and particular implementation issues are described for each file in specific detail.

Section 6 Baseline Results - presents summarized results of the Baseline simulation. It shows the state of the river as the Yampa model characterizes it under Baseline conditions. Both total flow and flow legally available to new development are presented for key sites.

Section 7 Calibration – describes the calibration process and demonstrates the model's ability to replicate historical conditions under historical demand and operations. Comparisons of streamflow, diversions, and reservoir levels are presented.

Appendixes – historical technical memoranda specific to the Yampa model, written at various phases of the model's development. The body of the manual contains references to other CDSS technical memos that are more general in scope, which are available at the CDSS website.

There is some overlap of topics both within this manual and between this and other CDSS documentation. To help the user take advantage of all sources, pointers are included as applicable under the heading "**Where To Find More Information**," throughout the manual.

2.3 What's in other CDSS documentation

The user may well find the need to supplement this manual with information from other CDSS documentation. This is particularly true for the reader who wants to:

- make significant changes to the Yampa model to implement specific future operations

- introduce changes that require regenerating the baseflow file

- regenerate input files using the Data Management Interface (DMI) tools and Hydrobase
- develop a StateMod model for a different basin

An ample body of documentation exists for CDSS, and is still growing. A user's biggest challenge may be in efficiently finding the information he needs. This list of descriptions is intended to help in selecting the most relevant data source:

Basin Information – the report "Yampa River Basin Information" is the first of its kind but is expected to be joined shortly by Basin Information reports for the other CDSS basins. It is a compendium of information on specific structures, operations, and practices within the basin. While the information was gathered in support of the planning model when it was first undertaken, it is widely useful to anyone doing any kind of water resources investigation or analysis.

DMI user documentation – user documentation for **StateDMI** and **TSTool** is currently available, and covers aspects of executing these codes against the HydroBase database (creating data sets for StateMod is only one aspect of their capabilities). The DMIs preprocess some of the StateMod input data, and TSTool provides summary and graphic review of both input and output. For example, StateDMI computed coefficients for distributing baseflow gains throughout the model and aggregated water rights for numerous small structures. TSTool filled missing time series data and computed headgate demands for irrigation structures. Thus the documentation, which explains algorithms for these processes, is helpful in understanding the planning model estimates. In addition, the documentation is essential for the user who is modifying and regenerating input files using the DMIs.

StateMod documentation – the StateMod user manual describes the model in generic terms and specific detail. Section 3 Model Description and Section 7 Technical Notes offer the best descriptions of StateMod functionality, and would enhance the Yampa model user's understanding of results. If the user is modifying input files, he should consult Section 4 Input Description to determine how to format files. To analyze model results in detail, he should review Section 5 Output Description, which describes the wide variety of reports available to the user.

StateCU documentation – StateCU is the CDSS irrigation consumptive use analysis tool. It is used to generate structure-specific time series of irrigation water requirement, an input to StateMod. A model change that involves modified irrigated acreage or crop-type would require re-execution of StateCU.

Self-documented input files – an important aspect of the Statemod input files is that their genesis is documented in the files themselves. Command files that directed the DMI's creation of the files are echoed in the file header. Generally, the model developers have incorporated comments in the command file that explain use of options, sources of data, etc.

Technical Memos – many aspects of the modeling methods adopted in CDSS were explored in feasibility or pilot studies before being implemented. Historical technical memoranda for these activities are available on the CDSS website:

- Phase IIIb Task Memorandum 10.1 – Data Extension Feasibility
- Phase IIIb Task Memorandum 10.2 – Evaluate Extension of Historical Data

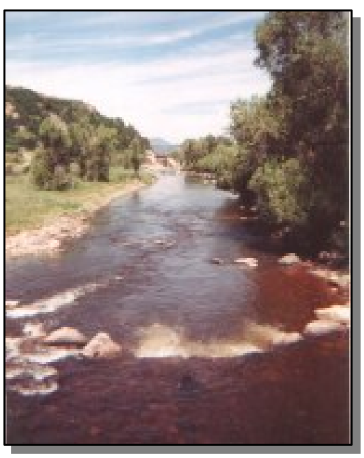
- Phase IIIb Task Memorandum 11.5 – Characterize Streamflow Data
- Phase IIIb Task Memorandum 11.7 – Verify Diversion Estimates
- Phase IIIb Task Memorandum 11.10 - Fill Missing Baseflow data (include Mixed Station Model user instruction)
- Daily Yampa Model Task Memorandum 1 – Equivalent daily return flow factors
- Daily Yampa Model Task Memorandum 2 – Pilot Study
- Daily Yampa Model Task Memorandum 3 – Selecting a Daily or Monthly Model
- Variable Efficiency Evaluation Task Memorandum 1.3 – Run StateMod to create baseflows using the Variable Efficiency and Soil Moisture Accounting Approach
- Variable Efficiency Evaluation Task Memorandum 1.5 – Compare StateMod Variable Efficiency and Soil Moisture Accounting Historical Model Results to Previous CDSS Model Results and Historical Measurements
- Variable Efficiency Evaluation Task Memorandum 1.5 – Compare StateMod Variable Efficiency and Soil Moisture Accounting Calculated Model Results to Previous CDSS Model Results and Historical Measurements
- CDSS Memorandum "Colorado River Basin Representative Irrigation Return Flow Patterns"

3. The Yampa River Basin

The Yampa River basin occupies Colorado's northwest corner, rising at the Continental Divide and ending at its confluence with the Green River, within miles of the Utah border. The basin encompasses most of Routt and Moffat counties in Colorado, the upper reaches of the Little Snake River basin in southern Wyoming, and a very small area of eastern Utah. Figure 1.1 is a map of the basin. The Yampa River flows through forested mountains, rural irrigated valleys, and desert canyons within Dinosaur National Monument. Many consider the Yampa the least-impacted of Colorado's mighty rivers.

3.1 Physical Geography

The Yampa River basin within Colorado is approximately 7,660 square miles in size, ranging in elevation from 12,200 feet in the headwaters near the town of Yampa to 5,600 feet in the vicinity of Dinosaur National Monument. Across this expanse, average annual rainfall varies from more than 60 inches near Rabbit Ears Pass, to approximately 10 inches near the State line. Temperatures generally vary inversely with elevation, and variations in the growing season follow a similar trend. Steamboat Springs has an average growing season of 86 days, while the growing season at Craig, Hayden, and Maybell has been estimated at approximately 120 days.

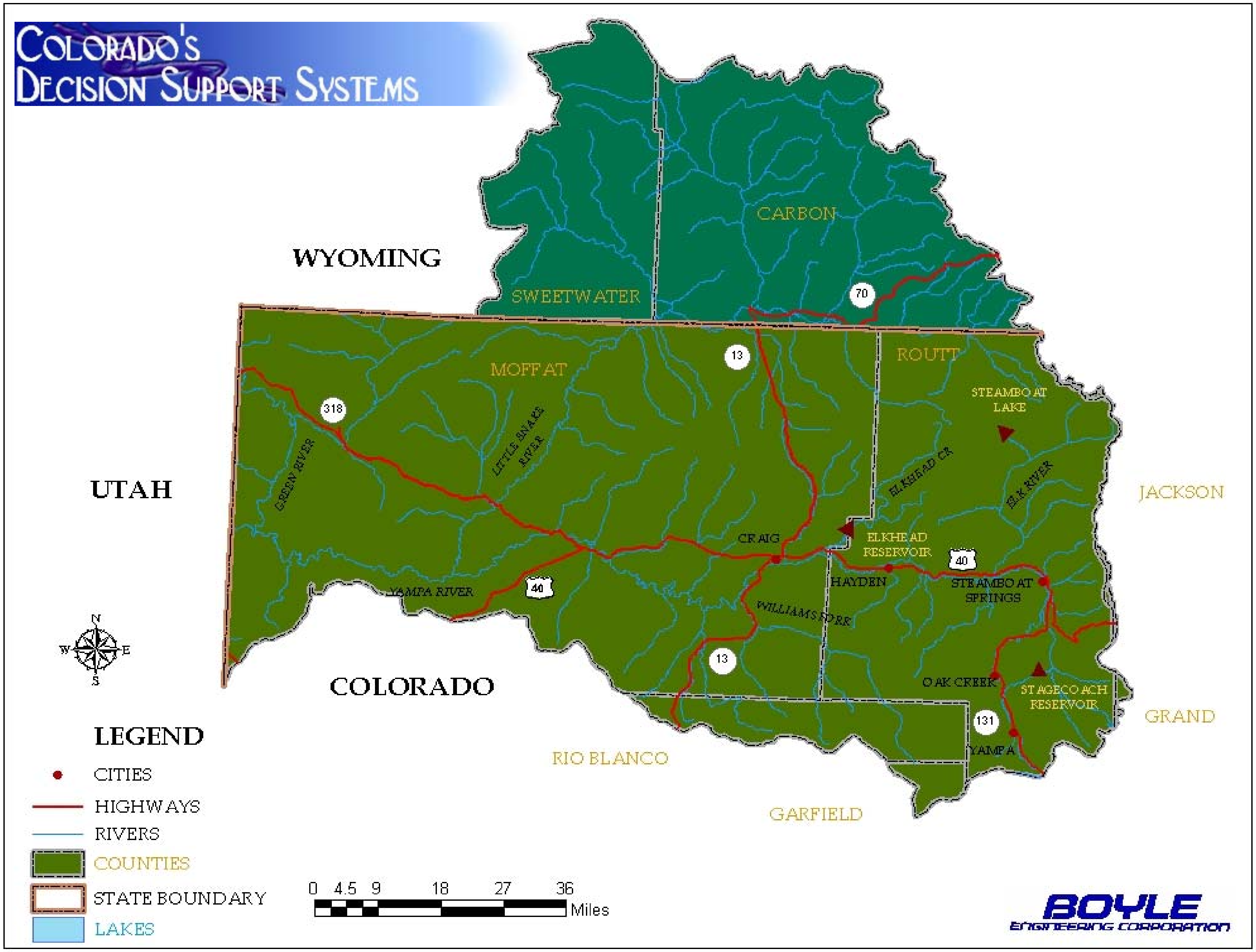


The Yampa River is the primary stream in the basin. It begins at the confluence of the Bear River and Chimney Creek, and other major tributaries include Walton Creek, Fish Creek, Trout Creek, Elk River, Elkhead Creek, Fortification Creek, the Williams Fork River, and the Little Snake River. Most of the water yield in the basin is attributable to snowmelt from the higher elevation areas near the Continental Divide. Average annual streamflow in the upper portions of the drainage (United States Geological Survey [USGS] gage near Stagecoach Reservoir) is approximately 56,000 acre-feet, which increases to an annual average of 1,490,000 acre-feet at the Dinosaur Monument (USGS gage near Deerlodge Park). Over 60 percent of this runoff occurs in May and June.

3.2 Human and Economic Factors

The discovery of gold near Hahn's Peak in the 1860's first drew permanent white settlers to the Yampa Valley. The mineral industry remains a key economic sector although coal and related energy activities are of greater importance than gold mining. Farming and ranching, as well as recreation and tourism, are the other primary activities in the basin today.

Figure 3.1 – Yampa River Basin



The area remains relatively sparsely populated, with the 2000 census placing the combined populations of Routt and Moffat Counties at approximately 33,000. Steamboat Springs and Craig are the major population centers in the basin, each with just under 10,000 residents. Routt County grew by about 40 percent during the 1990's, with growth concentrated in the upper Yampa Valley near Steamboat Springs. This growth attests to the importance of recreation-based activities, as people are drawn to the basin by the ski area and other outdoor recreation opportunities.

Principal water use in the basin is for irrigation, with hundreds of small irrigation ditches diverting from the main stem and the numerous tributary streams throughout the basin. The ditches irrigate pasture and hay and alfalfa crops primarily. The total irrigated acreage in the basin within Colorado, according to the State's irrigated average assessment of year 2000 imagery, is estimated to be approximately 89,800 acres.

Other major water uses include power generation at the Hayden Station and Craig Station plants, which have historically diverted approximately 16,100 acre-feet per year. There are also diversions for municipal use in Steamboat Springs and Craig, as well as in a number of smaller towns. Technically, the largest municipal user is Cheyenne, Wyoming. During the 1990's, Cheyenne's exports out of the headwaters of the Little Snake River in Wyoming averaged 15,400 af/yr. Within Colorado, three transbasin diversions, the Sarvis Ditch, Stillwater Ditch, and Dome Creek Ditch export water from the Yampa River basin to the Colorado River drainage. There are also a number of smaller transbasin diversions from one tributary drainage to another.

In addition to the direct ditch diversions, there are nine major reservoirs (greater than 4,000 acre-feet in capacity) in the Yampa River basin within Colorado. Three of the reservoirs are used for irrigation (Stillwater Reservoir No. 1, Allen Basin Reservoir, and Yamcolo Reservoir); three are predominantly used for recreational and fishery purposes (Lake Catamount, Pearl Lake, and Steamboat Lake); Fish Creek Reservoir serves municipal use; and the remaining reservoirs are used for multiple uses, including municipal, industrial, irrigation, and recreation (Stagecoach Reservoir, and Elkhead Reservoir). High Savery Reservoir in Wyoming began filling in 2005 and serves irrigators in Wyoming.

3.3 Water Resources Development

The Yampa River basin has seen water resources developments in the form of private irrigation systems, municipal and industrial diversions, and State-sponsored reservoir development. Table 3.1 summarizes key developments within the basin over time. Irrigation has remained relatively constant since the late 1800's, with only small increases in the irrigated acreage as new ditches and storage systems were constructed. The two earliest projects, Allen Basin and Stillwater Reservoirs, were built to relieve late summer irrigation shortages in the headwaters of the Bear River.

Table 3.1
Key Water Resources Developments

Date	Description	Date	Description
1939	Stillwater Reservoir	c. 1979	Cheyenne Stage II
1956	Fish Creek Reservoir	1981	Yamcolo Reservoir
1963	Craig Station Ditch and Pipeline	1988	Stagecoach Reservoir
1964	Cheyenne Stage I	1996	Fish Creek Reservoir enlargement
1965	Steamboat Lake	2003	High Savery Reservoir
1974	Elkhead Reservoir	2006	Elkhead Reservoir enlargement
1977	Lake Catamount		

Despite a general downturn in growth and economic activity in the Yampa Valley following World War II, the 1950's saw development of the first significant municipal system at Steamboat Springs. This downward trend in growth reversed itself in the mid-1960's, largely due to development of two large electric generating stations at Craig and Hayden, and the related resurgence of the northwest Colorado coal industry. Both the power plants use Yampa River water for cooling.

Echo Park

Later development reflects the rising importance of environmental and recreational uses, as well as the necessity of cooperative efforts and agreements. For example, Steamboat Lake was developed jointly by the Colorado Division of Parks and Outdoor Recreation and proponents of the Hayden Station Power Plant. Elkhead Reservoir similarly was a joint project of the Colorado Division Wildlife and the Yampa Project Participants who operate the Craig power plant. Yamcolo Reservoir was developed for irrigation, but its ability to supply water in the upper Bear River was enhanced through an exchange agreement with the multi-use Stagecoach Reservoir.

There are no Federal projects in the Yampa River basin, nor are there any main stem reservoirs below Steamboat Springs. During the 1950's, the Bureau of Reclamation proposed a dam at Echo Park as part of the Colorado River Storage Project, which would have inundated 46 miles of the Yampa and a comparable amount of the Green River. Controversy surrounded the region for more than a decade until a compromise was reached, in which Echo Park was foregone, and Glen Canyon Dam was built without any formal opposition.

3.4 Water Rights Administration

Historically, water right calls occur only on internally controlled tributaries where irrigation demands can exceed streamflows, such as Bear River, Fortification Creek, and North, Middle, and South Hunt Creeks. Irrigation shortages on the upper Bear River are typically satisfied by storage releases from

Yamcolo and Stillwater reservoirs. On the main stem there has not been administration of water rights calls and water has been available for appropriation.

The Upper Colorado River Basin Compact of 1948 specifies that Colorado may not deplete the flow in the Yampa River below an aggregate of 5 maf over any 10-year period. Average historical consumptive use, per the Colorado Decision Support System (CDSS) Yampa River Water Resources Planning Model, is on the order of 160,000 acre-feet/year on average. Therefore the Compact constraint is not limiting at current levels of development.

Future administration of the Yampa may be affected by activities and projects in the Recovery Program for Endangered Fish. Under the Endangered Species Act, four Colorado River native fish species are listed as endangered: Colorado pikeminnow (a.k.a. Colorado squawfish), humpback chub, bonytail chub, and razorback sucker. In 1988, the States of Colorado, Utah, and Wyoming, water users, hydropower customers, environmental organizations, and federal agencies developed a program to recover these species while allowing water use to continue and up to 50,000 acre-feet/year of new consumptive use to be developed.

The Recovery Program determined that 7,000 acre-feet of augmentation would satisfy adopted base flow recommendations for the Yampa River in all but the driest 10% of years. Eleven augmentation water supply alternatives were examined in detail, as described in the *Management Plan for the Yampa River Basin*. Alternatives include purchase or lease of water from one or more existing reservoirs and/or new or enlarged reservoirs, as well as supply interruption contracts. The Colorado Water Conservation Board (CWCB) recommends adoption of an alternative developed in August 2000 by a workgroup in Craig, Colorado. The specific elements of that alternative are as follows:

- Lease up to 2,000 acre-feet per year from Steamboat Lake.
- Enlarge Elkhead Reservoir to provide 3,700 acre-feet per year for late summer releases for endangered fish.
- The balance of augmentation (1,300 acre-feet) would likely be provided through a lease between the Recovery Program and Colorado River Water Conservation District (River District). This volume could be provided from the proposed human use pool at Elkhead and/or from a new tributary reservoir.

The Programmatic Biological Opinion (PBO) will not cap the amount of water that can be developed in the Yampa Basin. Rather, it will protect the right to develop a certain amount of water within a timeframe, whose impacts can be scientifically analyzed using the best available data. Implementation of the Recovery Program should allow Colorado to fully develop its entitlement to water under the compact.

3.5 Section 3 References

1. Colorado River Decision Support system Yampa River Basin Water Resourced Planning Model, Boyle Engineering Corporation and Riverside Technology, Inc., March 2000

2. //www.coloradofishing.net/ft-yampa.htm

3. Yampa and White River Basin Facts, Colorado Water Conservation Board, available at http://cwcb.state.co.us

4. The Yampa River Management Plan, Colorado Water Conservation Board, December 2001, available at http://cwcb.state.co.us

5. Yampa Valley Water Demand Study, BBC Research and Consulting, 1998.

6. Irrigation Water Use in the Yampa River Basin, Smith, D.H., Nichols, R.H., and Smith, F.M., Colorado State University, and Holt, Kent, Colorado Division of Water Resources, November 1998.

4. Modeling Approach

This section describes the approach taken in modeling the Yampa River basin, from a general perspective. It addresses scope and level of detail of this model in both the space and time domains, and describes how certain hydrologic processes are parameterized.

4.1 Modeling Objectives

The objective of the Yampa River modeling effort was to develop a water allocation and accounting model that water resources professionals can apply to evaluations of planning issues or management alternatives. The resulting “Baseline” input data set is one representation of current water use, demand, and administrative conditions, which can serve as the base in paired runs comparing river conditions without and with proposed future changes. By modifying the Baseline data set to incorporate the proposed features to be analyzed, the user can create the second input data set of the pair.

Moreover, the model was to estimate the basin’s consumptive use by simulating 100 percent of basin demand. This objective was accomplished by representing large or administratively significant structures at model nodes identified with individual structures, and representing many small structures at “aggregated” nodes. Although the model was first developed and calibrated for the period from 1975 forward, the data set was extended backward to 1909, creating a long-term data set reflecting a wide variety of hydrologic subsequences and conditions.

Another objective of the CDSS modeling effort was to achieve good calibration, demonstrated by agreement between historical and simulated streamflows, reservoir contents, and diversions when the model was executed with historical demands and operating rules. In fact, this objective was achieved as all twenty-two simulated gages are within one percent of historical values on an average annual basis, and most diversions are within a percentage point or two, again on an average annual basis.

4.2 Model coverage and extent

4.2.1 Network Diagram

Figure 4.1 is the network diagram for the Yampa River model. It includes over 350 nodes, beginning at Stillwater Reservoir in the Bear River basin and extending to the Colorado-Utah state line. The headwaters of the upper Little Snake River, which are in Wyoming, are in the model, as is the Green River within Colorado. Strictly speaking, the Yampa River basin does not include the Green River, as it is tributary to the Green. But a single diversion node representing Colorado’s use out of the Green was included to fulfill the CDSS modeling objective of representing all the

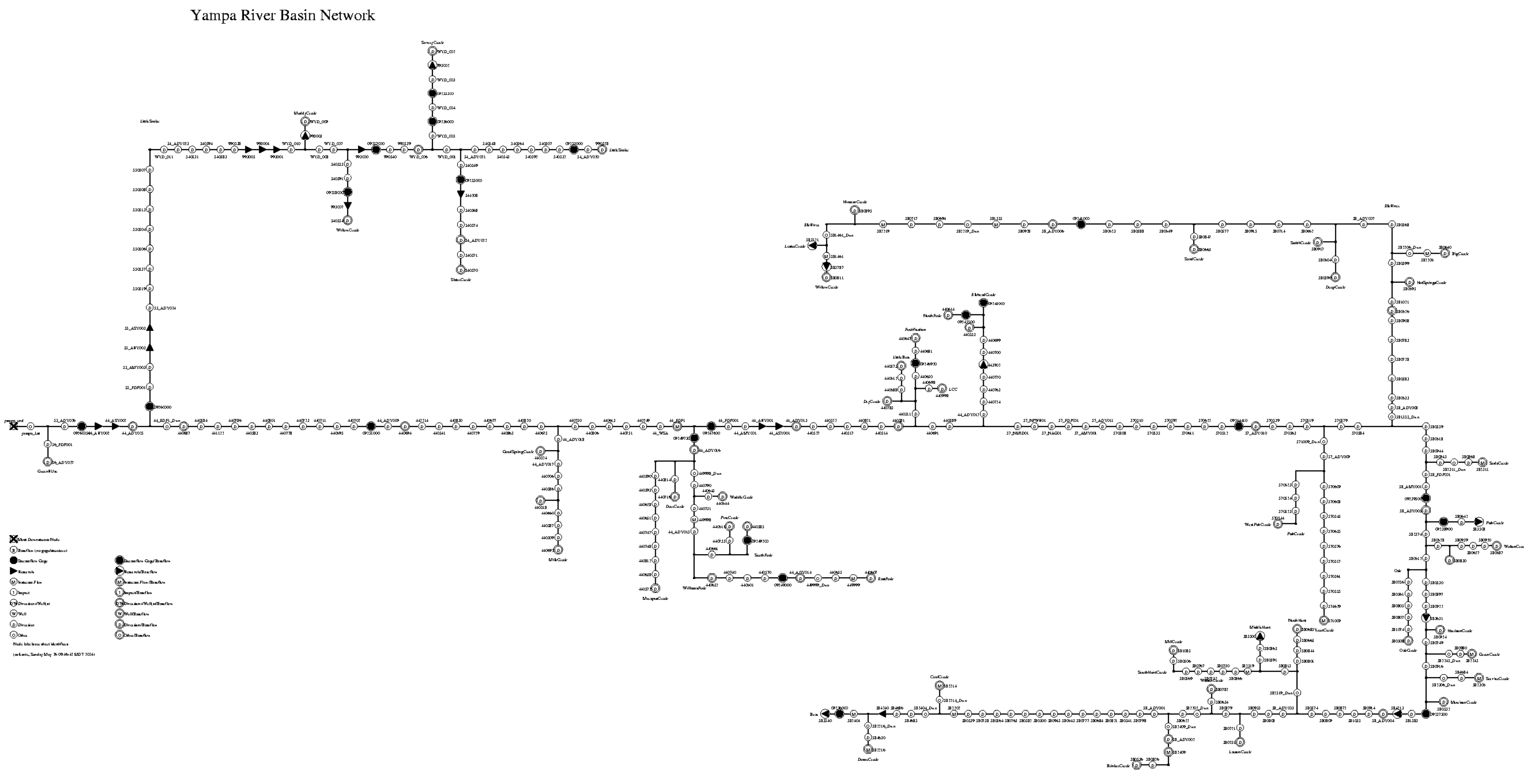


Figure 4.1 Network Diagram – Yampa River Planning Model

State's consumptive use of Colorado River water in its five West Slope models.

4.2.2 Diversion Structures

4.2.2.1 Key Diversion Structures

Early in the CDSS process it was decided that, while all consumptive use should be represented in the models, it was not practical to model each and every water right or diversion structure individually. Seventy-five percent of use in the basin, however, should be represented at strictly correct river locations relative to other users, with strictly correct priorities relative to other users. With this objective in mind, key structures to be "explicitly" modeled were identified by:

- Identifying net absolute water rights for each structure and accumulating each structure's decreed amounts
- Ranking structures according to net total absolute water rights
- Identifying the decreed amount at 75 percent of the basinwide total decreed amount in the ranked list
- Generating a structures/water rights list consisting of structures at or above the threshold decreed amount
- Field verifying structures/water rights, or confirming their significance with basin water commissioners, and making adjustments

Based on this procedure, a 5 cubic feet per second (cfs) cutoff value was selected for the Yampa River basin. Key diversion structures are those with total absolute water rights equal to or greater than 5.0 cfs. The Yampa River model includes approximately 240 key diversion structures. Two key diversion structures are in Wyoming on the Little Snake River.

> Where to find more information
>
> - Section 3 of the CDSS document "Yampa River Basin Information" lists candidate key structures and in some cases indicates why structures were or were not designated as "key". These decisions were often based on Water Commissioner input which is also documented in the Yampa Basin Information section "Division 6 Meeting".

4.2.2.2 Aggregation Of Irrigation Structures

The use associated with irrigation diversions having total absolute rights less than 5.0 cfs were included in the model at "aggregated nodes." These nodes represent the combined historical diversions, demand, and water rights of many small structures within a prescribed sub-basin. The aggregation boundaries were based generally on tributary boundaries, or if on the mainstem, gage location, critical administrative reaches, and instream flow reaches. To the extent possible, aggregations were devised so that they represented no more than 1500 irrigated acres. In the Yampa River model within Colorado, 27 aggregated nodes were identified, representing nearly 25,000 acres of irrigated crops. Generally, these nodes were placed in the model at the most downstream position within the aggregated area.

Aggregated irrigation nodes were attributed all the water rights associated with their constituent structures. Their historical diversions were developed by summing the historical diversions of the individual structures, and their irrigation water requirement is based on the total acreage associated with the aggregation.

Irrigation use in Wyoming was represented primarily with aggregated nodes, of which there are ten on the Wyoming side of the border. Characteristics of these aggregations were obtained from the GRBP technical memoranda and supporting spreadsheets .

Where to find more information

- Appendix A contains memoranda related to aggregation of irrigation structures. The first documents a recent update by Leonard Rice Engineers, based on year 2000 imagery. The current model reflects this information. A table in the memo shows what diversion structures are included in each aggregation. The second memo describes the original aggregation, based on year 1993 imagery. It is included because some of the updates in the recent memo are described in terms of modifications to the original aggregations.

- Appendix A also includes a memorandum describing the task in which aggregated nodes were placed in the model network.

4.2.2.3 Aggregation of Municipal and Industrial Uses

Four nodes in the model represent the combined small diversions for municipal, industrial, and livestock use within Colorado. Total non-irrigation consumptive use in Colorado's portion of the Yampa basin was estimated relatively early in CDSS development, as documented in the memorandum "Consumptive Use Model Non-Irrigation Consumptive Uses and Losses in the Yampa River Basin." (see Appendix B). Consumptive use of the key municipal and industrial diversions in the model was subtracted from this basinwide M&I consumption, to derive the basinwide consumptive use attributable to small M&I users. This value was distributed to Water Districts 44, 55, 57, and 58 in accordance with a general distribution of M&I use identified by BBC Research and Consulting in their 1998 "Yampa Valley Water Demand Study."

The four aggregated M&I nodes represent approximately 2600 af of consumptive use, a small percentage of the basin total use. Their demands are represented as being the same each year, based on annual averages. These diversions have a priority of 1.0 (very senior) in the model, and a decreed amount that greatly exceeds their demands. In other words, these structures' diversions are not limited by their water right. The monthly demands (which are set to the consumptive use rather than diversion amount) were set in accordance with results of the BBC investigation cited above.

One node on the Little Snake River in Wyoming represents the combined diversions of the Towns of Baggs and Dixon, Wyoming. This is the only M&I use identified in the Little Snake basin by the GRBP, other than Cheyenne's transmountain project, which is represented explicitly. Like the Colorado aggregated M&I nodes, this node's demands are modeled as being the same each year, based on annual averages.

Where to find more information

- Appendix B includes a memorandum describing the task in which municipal and industrial uses were aggregated. The memo describes the original, somewhat complicated attempt to achieve geographic distribution of the aggregated M&I use, and the later simplification that became available through the Yampa Valley Water Demand Study. Appendix B also includes CRDSS Task 2.09-12 Memorandum "Consumptive Use Model Non-Irrigation Consumptive Uses and Losses in the Yampa River Basin", November 1996.
- "Yampa Valley Water Demand Study", BBC Research and Consulting, June 30, 1998. The study is currently available in .pdf format from the Colorado River Water Conservation District's website, www.crwcd.gov

4.2.3 Reservoirs

4.2.3.1 Key Reservoirs

Reservoirs with decreed capacities equal to or in excess of 4,000 acre-feet are considered key reservoirs, and are explicitly modeled. In addition, the 2,250-af Allen Basin Reservoir is included because it is involved with some trans-tributary diversions that were more readily modeled by including the reservoir operations. Excluding Wyoming reservoirs, there are nine key reservoirs with a combined total capacity of approximately 108,000 af, or 80 to 90 percent of the total absolute storage rights of the basin within Colorado. High Savery Reservoir and several small impoundments are modeled in

Wyoming. Physical parameters for the Wyoming structures were provided by the Wyoming Water Development Commission, by way of the Wyoming State Engineer's office.

4.2.3.2 Aggregation of Reservoirs

In keeping with CDSS's objective of representing all consumptive use in the basin, the evaporation losses associated with small reservoirs were incorporated using six aggregated reservoir structures within Colorado and four aggregated structures in Wyoming.

Three of the six Colorado structures were used to represent all the adjudicated, absolute storage rights in the database that are otherwise unaccounted for. Reservoir 44_ARY001, although placed in the network at the top of Water District 44, represents storage rights in districts 57 and 58. Reservoir 44_ARY002 represents District 44 storage, and reservoir 55_ARY003 represents storage in Districts 55 and 56. Table 4.1 below summarizes storage capacity for the three reservoirs. Surface area for the reservoirs was developed assuming they are straight-sided pits with a depth of 24 feet. According to comments in the reservoir structure file, this number was based on Dam Safety records as summarized in an unpublished U.S. Bureau of Reclamation effort.

Table 4.1
Aggregated Reservoirs

ID	WD	Name	Capacity (AF)	%
44_ARY001	57&58	ARY_001_YampaRbelCraig	23,206	69
44_ARY002	44	ARY_002_YampaR@Deerlodge	9,122	27
55_ARY003	54&55	ARY_003_LSnakeRnrLily	1,494	4
		Total	33,822	100

The three remaining Colorado reservoirs represented stockpond use, as documented in CDSS Task Memo 2.09-12, "Consumptive Use Model Non-Irrigation Consumptive Uses and Losses in the Yampa River Basin". Each represents stockponds within a hydrologic unit, as presented in the task memo and shown below in Table 4.2. The stockponds were modeled as 10-foot deep straight sided pits. Locations, sizes, and total evaporation amount for the aggregated Wyoming reservoirs were provided either by the Wyoming State Engineer's Office or the GRBP.

Neither the aggregated reservoirs nor the stockponds release to the river in the models. They evaporate, however, and fill to replace the evaporated amount. The effects of small reservoirs filling and releasing are left "in the gage" in the model, and are reflected in CDSS baseflow computations. The aggregated reservoirs are assigned storage rights with a priority of 1.0 (very senior) so that the evaporation use is not constrained by water rights.

Table 4.2
Aggregated Stockponds

ID	HUC	Name	Capacity (AF)	%
44_ASY001	14050001	ASY_001_YampaRbelCraig	8,344	52
44_ASY002	14050002	ASY_002_YampaR@Deerlodge	4,441	28
55_ASY003	14050003	ASY_003_LSnakeRnrLily	3,173	20
		Total	15,958	100

Where to find more information

- Appendix B includes a task memo describing the original effort to aggregate small reservoir use, as well as some later simplifying changes. It also includes CDSS Task 2.09-12 Memorandum "Consumptive Use Model Non-Irrigation Consumptive Uses and Losses in the Yampa River Basin", November 1996.
- Appendix C contains memos that relate to representation of Wyoming depletions, including those due to reservoir evaporation.

4.2.4 Instream Flow Structures

The model includes 16 instream flow reaches representing instream flow rights held by CWCB. These are only a subset of the total CWCB tabulation of rights because many instream flow decrees are for stream reaches very high in the basin, above the model network.

4.3 Modeling Period

The Yampa River model data set extends from 1909 through 2005. The calibration period was 1975 through 2005, a period selected because historical diversion data were readily available in electronic format for key structures. In addition, the period reflects most recent operations in the basin, and includes both drought (1977, 1989-1992, 2002) and wet cycles (1983-1985).

As one goes back in time within the data set, more and more data are estimated. Before extending the data set, a feasibility study was done which included a survey of available data and methods for data extension. The scope of the study included all five West Slope planning models.

Where to find more information

- The feasibility study for the data extension is documented in two task memos, which are available at the CDSS website:

  -Phase IIIb Task Memo 10.1 Data Extension Feasibility

  -Phase IIIb Task Memo 10.2 Evaluate Extension of Historical Data

4.4 Data Filling

In order to extend the data set to 1909, a substantial amount of reservoir content, diversion, demand, and baseflow time series data needed to be estimated. Generally, HydroBase data begins in 1975, although for some structures there is additional, earlier historical data. Therefore, major structures were selected for additional investigation outside the database, or outside the standard CDSS data tables in the case of reservoir contents. CDSS tools were then developed to automate the estimation process for the remaining structures. This section describes data filling and extension for the Yampa River basin model.

4.4.1 Historical Data Extension For Major Structures

4.4.1.1 Historical Diversions

Based primarily on the size of their historical diversions, the Maybell Canal, Walton Creek Ditch, and Gibralter Ditch were identified as warranting additional investigation to find actual diversion records prior to 1975. As it turned out, the database for these structures was already fairly complete, beginning in the mid-1920's or early 1930's. The microfiche records at the Division of Water Resources yielded three additional years of data for the Maybell Canal and four additional years for the Gibralter Ditch. These few additional years were incorporated in the model input data set.

4.4.1.2 Historical Reservoir Contents

The four largest reservoirs in the Yampa River basin are fairly recent developments, as shown by the list of major Yampa basin reservoirs below. Historical information prior to 1975 was sought from Division 6 for Steamboat Lake without success, and therefore had to be filled in using the automated data filling procedure used for less significant structures. Division 6 provided content information on Stagecoach Reservoir from December, 1988 forward. Post-1975 data were in the database for Yamcolo Reservoir, Steamboat Lake, and Elkhead Reservoir, but it was determined that the monthly reservoir content table was sparsely populated. A more complete time series was developed for these three reservoirs by taking reservoir contents from the sporadic observations table, using only observations within 16 days of month's end.

WDID	Reservoir Name	Capacity (af)	First Year of Operation
584240	YAMCOLO	9,096	1981
584213	STAGECOACH	32,275	1988
443902	ELKHEAD	13,699	1975
583787	STEAMBOAT LAKE	23,064	1965

4.4.2 Automated Time Series Filling

An automated procedure was adopted to fill time series (i.e., historical diversions, demand, historical reservoir contents, reservoir targets, and irrigation water requirement) input to the model. It is a refinement over using an overall monthly average as the estimated value. Each month of the modeling period has been categorized as an Average, Wet, or Dry month based on the gage flow at long-term “indicator” gages in the Yampa basin. A data point missing for a Wet March, for example, is then filled with the average of only the Wet Marches in the partial time series, rather than all Marches.

The process of developing the Average, Wet, and Dry designation for each month is referred to as “streamflow characterization”. There are three streamflow characterizations in the Yampa basin, based on three indicator gages: Little Snake River at Lily (09260000), Yampa River at Maybell (09251000), and Yampa River at Steamboat Springs (09239500). The characterization for the Lily gage is used when filling in time series for any structure in District 55, as well as the two lowest Wyoming aggregates. Similarly, the Maybell gage characterization pertains to District 44 and District 56, and the Steamboat Springs gage characterization pertains to Districts 54, 57, 58, and the upper Little Snake basin. Months with gage flows at or below the 25^{th} percentile for that month are characterized as “Dry”, while months at or above the 75^{th} percentile are characterized as “Wet”, and months with flows in the middle are characterized as “Average”.

When historical diversion records are filled, a constraint is added to the estimation procedure. The estimated diversion may not exceed the water rights that were available to the diversion at the time. For example, if a ditch was enlarged and a junior right added to it in the 1950’s, then a diversion estimate for 1935 cannot exceed the amount of the original right. The date of first use is derived from the administration number of the water right, which reflects the appropriation date.

Where to find more information

- A proof-of-concept effort with respect to the automated data filling process produced the following task memos, which are available at the CDSS website:

  -Phase IIIb Task Memo 10.1 Data Extension Feasibility

  -Phase IIIb Task Memo 10.2 Evaluate Extension of Historical Data

  -Phase IIIb Task Memo 11.5 Characterize Streamflow Data

  -Phase IIIb Task Memo 11.7 Verify Diversion Estimates

  These memos describe rationale for the data-filling approach, explore availability of basic gage data, explain the streamflow characterization procedure, and provide validation of the methods.
- Documentation for the Streamflow Characterization Tool, a calculator for categorizing months as Average, Wet, or Dry, is under development.
- Tstool and StateDMI documentation describes how to invoke the automated data filling procedure using those DMI's

4.4.3 Baseflow Filling

A typical approach to filling missing hydrologic sequences in the process of basin modeling is to develop regression models between historical stream gages. The best fitting model is then applied to estimate missing data points in the dependent gage's record. Once gage flow time series are complete, observed or estimated diversions, changes in storage, and so forth are added to or subtracted from the gage value to produce an estimated naturalized flow or baseflow.

The typical approach was deemed inadequate for a study period that extended over decades and greatly changed operating environments. Gage relationships derived from late-century gage records probably are not applicable to much earlier conditions, because the later gages reflect water use that may not have been occurring at the earlier time. The CDSS approach is therefore to estimate baseflows at all points where actual gage records are available, and then correlate between naturalized flows, as permitted by availability of data. Ideally, since baseflows do not reflect human activity, the relationship between two sets of baseflows is independent of the resource use and can be applied to any period.

Baseflow filling is carried out more or less automatically using the USGS Mixed Station Model, enhanced for this application under the CDSS project. The name refers to its ability to fill many series, using data from all available stations. Many independent stations can be used to fill one time series, but only one station is used to fill each individual missing value. The Mixed Station Model fits each combination of dependent and independent variable with a linear regression relationship on log-transformed values, using the common period of record. For each point to be filled, the model then selects the regression that yields the least standard error of prediction (SEP), among all eligible correlations.

In reality, the further one goes back in time, the fewer gage records exist to create baseflow series that can serve as independent variables. In 1909, were no gages in the Yampa River basin, and there were fewer than three USGS stations in the basin until the mid-1930's. To fill baseflows during these early periods, long-term historical gages outside the Yampa basin were added to the list of potential independent variables available to the Mixed Station Model. Approximately 55 percent of the gage site baseflows are filled. These are split almost evenly between baseflows estimated from gage site baseflows within the Yampa River basin, and those estimated from gage site baseflows outside the basin.

Where to find more information

- The task memorandum documenting application of the Mixed Station Model to CDSS baseflows is entitled "Subtask 11.10 Fill Missing Baseflows" and is available at the CDSS website. It describes a sensitivity investigation of the use of historical gage data in lieu of baseflow estimates when the latter is unavailable.
- Documentation for the Mixed Station Model and its GUI is under development. The task memo cited above contains user instructions.

4.5 Consumptive Use And Return Flow Amounts

The related values consumptive use and return flow are key components of both baseflow estimation and simulation in water resources modeling. StateMod's baseflow estimating equation includes a term for return flows. Imports and reservoir releases aside, water that was in the gage historically is either natural runoff or delayed return flow. To estimate the natural runoff, or more generally, the baseflow, one must estimate return flow. During simulation, return flows affect availability of water in the stream in both the month of the diversion and subsequent months.

For non-irrigation uses, consumptive use is the depletive portion of a diversion, the amount that is taken from the stream and removed from the hydrologic system by virtue of the beneficial use. The difference between the diversion and the consumptive use constitutes the return flow to the stream.

For irrigation uses, the relationship between crop consumptive use and return flow is complicated by interactions with the water supply stored in the soil, i.e., the soil moisture reservoir, and losses not attributable to crop use. This is explained in greater detail below.

4.5.1 Variable Efficiency Of Irrigation Use

Generally, the efficiency of irrigation structures in the Yampa model is allowed to vary through time, up to a specified maximum efficiency. Setting aside soil moisture dynamics for the moment, the predetermined crop irrigation water requirement is met out of the simulated headgate diversion, and efficiency (the ratio of consumed water to diverted water) falls where it may – up to the specified maximum efficiency. If the diversion is too small to meet the irrigation requirement at the maximum efficiency, maximum efficiency becomes the controlling parameter. Crop consumption is limited to the diverted amount times maximum efficiency, and the balance of the diversion, less 3 percent (generally) incidental losses, returns to the stream.

The incidental loss of non-consumed water refers to water lost to the hydrologic system altogether, through, for example, non-crop consumptive use, deep groundwater storage, or evaporation. The loss factor was set to 3 percent throughout most of the Yampa model. This default value is based on USBR's basinwide estimate of incidental loss, which they express as a fraction of crop consumptive use. It was recommended in an earlier CDSS study, and is the same value used in the StateCU estimate of Consumptive Use and Losses in the Colorado River Basin. (Consumptive Uses and Losses Report, Comparison between StateCU CU & Losses Report and the USBR CU & Losses Report (1991-1995), October 1999, Leonard Rice Engineers). During calibration, the loss factor was set to 10 percent in the lower Little Snake River basin, based on the relationship between the Dixon and Lily gages. This area is warmer and drier than the rest of the Yampa basin, and the greater loss factor resulted in better simulation of the gages.

The model is supplied with time series of irrigation water requirements for each structure, based on its crop type and irrigated acreage, using the Blaney-Criddle method outlined in Irrigation Water Requirements Technical Release 21 (1970). For Colorado structures, this information was generated using the CDSS StateCU model. For Wyoming structures, a time series of irrigation water requirement was built from monthly irrigation water requirements for Normal, Wet, and Dry years, per the GRBP. Maximum efficiency is also input to the model, and is assumed to be 0.54 for all Colorado structures in the Yampa model. For Wyoming structures, the maximum efficiency from the GRBP (0.55) was adopted.

Headgate diversion is determined by the model, and is calculated in each time step as the minimum of 1) the water right, 2) available supply, 3) diversion capacity, and 4) headgate demand. Headgate demand is input as a time series for each structure. During calibration, headgate demand for each structure is simply its historical diversion time series. In the Baseline data set, headgate demand is an estimate of the diversion required in order to deliver the crop requirement (see Section 4.9.1 for details). Historical efficiency is defined as the smaller of 1) average historical diversion for the month, divided by average irrigation water requirement, and 2) maximum efficiency. In other words, if water supply is generally plentiful, the headgate demand reflects the water supply that has been typical in the past; and if water supply is generally limiting, it reflects the supply the crop needs in order to satisfy potential ET at the maximum efficiency.

Now StateMod also accounts for water supply available to the crop from the soil. Soil moisture capacity acts as a small reservoir, re-timing physical consumption of the water, and affecting the amount of return flow in any given month. Soil moisture capacity is input to the model for each irrigation structure, based on NRCS mapping. Formally, StateMod accounts for water supply to the crop as follows:

Let **SW** be defined as surface water available to the crop, i.e., river diversion times maximum efficiency, and let $\mathbf{CU_i}$ be defined as irrigation water requirement. Then,

when $SW \geq CU_i$:

$CU_w = CU_i$

$SS_f = SS_i + \min[(SS_m - SS_i),(SW - CU_i)]$

$SR = SW - CU_i - (SS_f - SS_i)$

$TR = (1.0 - ILF) * (SR + (1.0 - \eta_{max}) * \text{diversion})$

And when $SW < CU_i$:

$CU_w = SW + \min[(CU_i - SW), SS_i]$

$SS_f = SS_i - \min[(CU_i - SW), SS_i]$

$SR = 0$

$TR = (1.0 - ILF) * ((1.0 - \eta_{max}) * \text{diversion})$

where CU_w is water supply limited consumptive use;

SS_m is the maximum soil moisture reservoir storage;

SS_i is the initial soil moisture reservoir storage;

SS_f is the final soil moisture reservoir storage;

SR is the delivered water in excess of crop requirement;

η_{max} is the maximum efficiency; and

TR is the total return to the stream attributable to this month's diversion.

ILF is the incidental loss factor (3 percent for most of the Yampa basin)

More descriptively, it is assumed that 54 percent of the diverted amount can be delivered and available to the crop. When this amount exceeds the irrigation water requirement, the balance goes to the soil moisture reservoir, up to its capacity. Additional water returns to the stream, subject to the incidental loss, along with the 46 percent delivery inefficiency, also subject to incidental losses. In this case, the crop needs are completely satisfied, and the potential consumptive use (crop water requirement) is fully realized.

When 54 percent of the diverted amount is less than the irrigation water requirement, the crop pulls water out of soil moisture storage, limited by the available soil moisture and the unsatisfied irrigation water requirement. Consumptive use is the sum of supply due to the diversion and supply taken from soil moisture, and may be less than the crop water requirement. Total return flow is the 46 percent of the diversion deemed unable to reach the field, less the incidental loss.

With respect to consumptive use and return flow, aggregated irrigation structures are treated as described above, where the irrigation water requirement is based on total acreage for the aggregate.

4.5.2 Constant Efficiency For Other Uses And Special Cases

In specific cases, the Yampa model applies an assumed, specified monthly efficiency to a diversion in order to determine consumptive use and return flows. Although the efficiency varies by month, the monthly pattern is the same in each simulation year. This approach is applied to municipal, industrial, and transbasin users, as well as any irrigation diversion for which crop water requirement has not been developed.

The four basin exporters in the Yampa model (Stillwater Ditch, Sarvis Ditch, Dome Creek Ditch, and City of Cheyenne) have been assigned a diversion efficiency in all months of 1.00. During both baseflow estimation and simulation, the entire amount of the diversion is assumed to be removed from the hydrologic system. The two explicitly modeled municipal systems in Colorado (Craig and Steamboat Springs/Mt. Werner) have been given typical monthly efficiencies that reflect indoor use only in the winter, and combined indoor and outdoor use during the irrigation season. Efficiency for the municipal diversion representing the Towns of Baggs and Dixon in Wyoming was based on annual efficiencies available in the GRBP. Snowmaking has been assigned an efficiency of .80, based on industry estimates and recent decrees. Cooling water demand at the Hayden and Craig stations has an efficiency of 1.00 because there are no returns to the river.

Finally, every structure in the model, including irrigation structures operating by variable efficiency, has monthly efficiencies assigned to it in the model input files. For irrigation structures, these are average monthly efficiencies based on historical diversions and historical crop water requirement over the period 1950-2005, but may not exceed 0.54. These are used by DMI components of CDSS to create time series of headgate demands for input to the model, as described in Section 4.9.1.

Where to find more information

- StateCU documentation describes different methods for estimating irrigation water requirement for structures, for input to the StateMod model.
- Section 7 of the StateMod documentation has subsections that describe "Variable Efficiency Considerations" and "Soil Moisture Accounting"
- Section 5 of this manual describes the input files where the parameters for computing consumptive use and return flow amounts are specified:
  - Irrigation water requirement in the Irrigation Water Requirement file (Section 5.5.3)
  - Headgate demand in the Direct Diversion Demand file (Section 5.4.4)
  - Historical efficiency in the Direct Diversion Station file (Section 5.4.1)
  - Maximum efficiency in the CU Time Series file (Section 5.5.2)
  - Soil moisture capacity in the StateCU Structure file (Section 5.5.1)
  - Loss to the hydrologic system in the Delay Table file (Section 5.4.2)

4.6 Disposition of Return Flows

4.6.1 Return Flow Timing

Return flow timing is specified to the model by specifying what percentage of the return flow accruing from a diversion reaches the stream in the same month as the diversion, and in each month following the diversion month. Four different return flow patterns are used in the Yampa River model. One represents instantaneous (or within the same month as the diversion) returns and is applied to municipal and non-consumptive diversions. A second pattern places 100 percent of the diversion return in the fourth month following the diversion. This pattern is used for returns from artificial snowmaking.

The last two patterns are generalized irrigation return patterns, applicable to irrigated lands subject to 3 percent loss for one pattern, and 10 percent loss for the other. The basic return pattern was developed using the Glover analytical solution for parallel drain systems. The State's Analytical Steam Depletion Model (September, 1978), which is widely used in determining return flows for water rights transfers and augmentation plans, permits this option for determining accretion factors.

The Glover analysis requires these input parameters:

T = Transmissivity in gallons per day per foot (gpd/ft). Transmissivity is the product of hydraulic conductivity (K) in feet per day, saturated thickness (b) in feet, and the appropriate conversion factor.

S = Specific Yield as a fraction

W = Distance from stream to impervious boundary in feet (ft)

x = Distance from point of recharge to stream in feet (ft)

Q = Recharge Rate in gallons per minute (gpm)

Regionalized values for the aquifer parameters were determined by selecting ten representative sites throughout the west slope, based partly on the ready availability of geologic data, and averaging them. The analysis estimated generalized transmissivity as 48,250 gpd/ft, specific yield as 0.13, distance from the stream to the alluvial boundary as 3,500 ft. The Glover analysis was then executed for both a distance of 600 feet from the recharge center to the stream, and 1500 feet from the recharge center to the stream. (Currently, the pattern resulting from the shorter distance is used in the model.)

It was assumed that the resulting pattern applies to only half of the return flow, and that the other half returns within the month via the surface (tailwater returns, headgate losses, etc.). It was also assumed that incidental losses occur due to processes such as evaporation and non-beneficial consumptive use. In the one case, losses of 3 percent occur in the first return month. In the second case, 10 percent loss is spread over the first two return months, with 7 percent occurring in the first month, and 3 percent occurring in the second month. The patterns listed in Table 4.3, and graphed in Figure 4.2, show the net result for these assumptions imposed on the Glover analysis, that is, that the irrigation return patterns supplied to the model reflect combined surface and groundwater returns, and that non-beneficial loss occurs at a specified level. Month 1 is the month in which the diversion takes place.

Where to find more information

- CDSS Memorandum “Colorado River Basin Representative Irrigation Return Flow Patterns”, Leonard Rice Engineers, January, 2003. Available at the CDSS website.

4.6.2 Return Flow Locations

Return flow locations were determined during the original data gathering, by examining irrigated lands mapping and USGS topographical maps, and confirming locations with Division 6 personnel. Some return flow locations were modified during calibration.

Table 4.3
Percent of Return Flow Entering Stream in Month n after Diversion

Month *n*	With 3 percent Incidental Loss	With 10 percent Incidental Loss
1	75.6	71.6
2	11.3	8.3
3	3.2	3.2
4	2.2	2.2
5	1.6	1.6
6	1.2	1.2
7	0.8	0.8
8	0.6	0.6
9	0.5	0.5

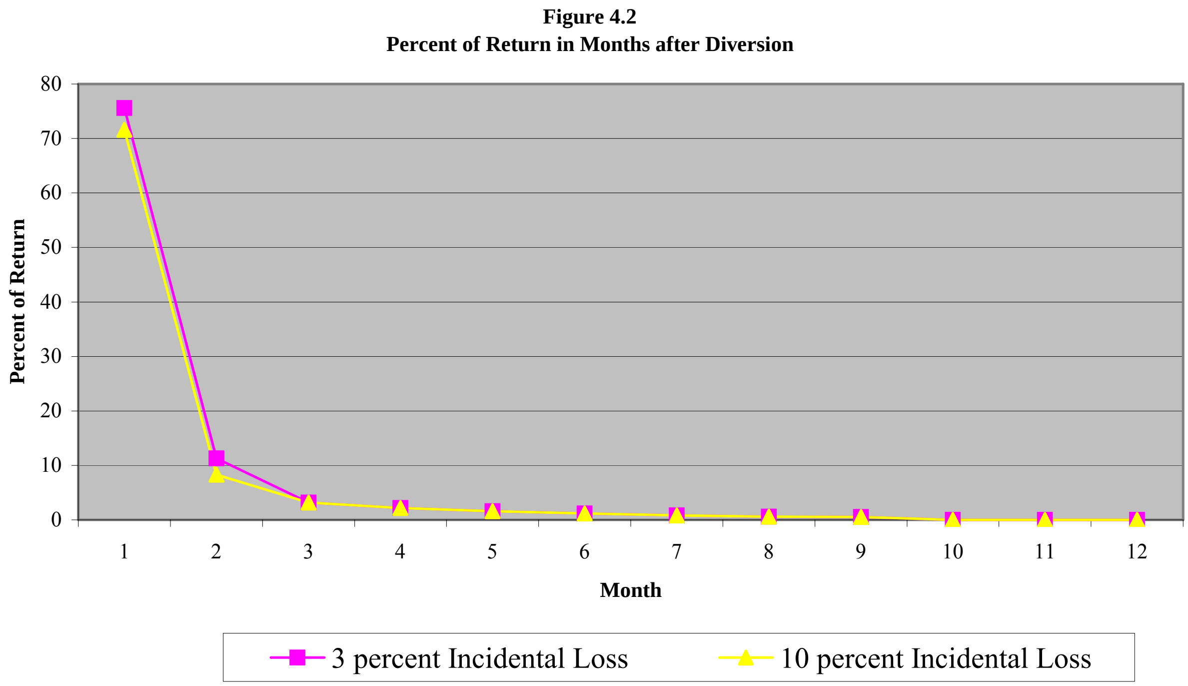


Figure 4.2 Percent of Return in Months After Diversion

4.7 Baseflow Estimation

In order to simulate river basin operations, the model must have at hand the amount of water that would have been in the stream if none of the operations being modeled had taken place. These undepleted flows are called "baseflows". The term is used in favor of "virgin flow" or "naturalized flow" because it recognizes that some historical operations can be left "in the gage", with the assumption that those operations and impacts will not change in the hypothetical situation being simulated.

Given data on historical depletions and reservoir operations, StateMod can estimate baseflow time series at specified discrete inflow nodes. This process was executed prior to executing any simulations, and the resulting baseflow file became part of the input data set for simulations. Baseflow estimation requires three steps: 1) adjust USGS stream gage flows using historical records of operations to get baseflow time series at gaged points, for the gage period of record; 2) fill the baseflow time series by regression against other baseflow time series; 3) distribute baseflow gains above and between gages to user-specified, ungaged inflow nodes. These three steps are described below.

4.7.1 Baseflow Computations At Gages

Baseflow at a site where historical gage data is available is computed by adding historical values of all upstream depletive effects to the gaged value, and subtracting historical values of all upstream augmenting effects from the gaged value:

$$Q_{baseflow} = Q_{gage} + Diversions - Returns - Imports +/- \Delta Storage + Evap +/- \Delta Soil\ Moisture$$

Historical diversions, imports, and reservoir contents are provided directly to StateMod to make this computation. Evaporation is computed by StateMod based on historical evaporation rates and reservoir contents. Return flows and soil storage are similarly computed based on diversions, crop water requirements, and/or efficiencies as described in Section 4.5, and return flow parameters as described in Section 4.6.

Where to find more information

- When StateMod is executed to estimate baseflows at gages, it creates a Baseflow Information file *(*.xbi)* that shows this computation for each gage and each month of the time step.

4.7.2 Baseflow Filling

Wherever gage records are missing, baseflows are estimated as described in Section 4.4.3 Baseflow Filling.

4.7.3 Distribution Of Baseflow To Ungaged Points

In order for StateMod to have a water supply to allocate in tributary headwaters, baseflow must be estimated at all ungaged headwater nodes. In addition, baseflow gains between gages are modeled as entering the system at ungaged points, to better simulate the river's growth due to generalized groundwater contributions and unmodeled tributaries. As a matter of convention, key reservoir nodes were designated baseflow nodes in order for the model to "see" all the water supply estimated to be available at the site. During calibration, other ungaged nodes were sometimes made baseflow nodes to better simulate a water supply that would support historical operations.

StateMod has an operating mode in which, given baseflows at gaged sites and physical parameters of the gaged and ungaged sub-basins, it distributes baseflow gains spatially. The default method ("gain approach") for assigning baseflow to ungaged locations pro-rates baseflow gain above or between gages according to the product of drainage area and average annual precipitation. That is, each gage is assigned an "Area*Precipitation" (A*P) term, equal to the product of total area above the gage, and average annual precipitation over the gage's entire drainage area. Ungaged baseflow points are assigned an incremental "A*P", the product of the incremental drainage area above the ungaged baseflow point and below any upstream gages, and the average annual precipitation over that area. Figure 4.3 illustrates a hypothetical basin and the areas associated with each of three gages and an ungaged location.

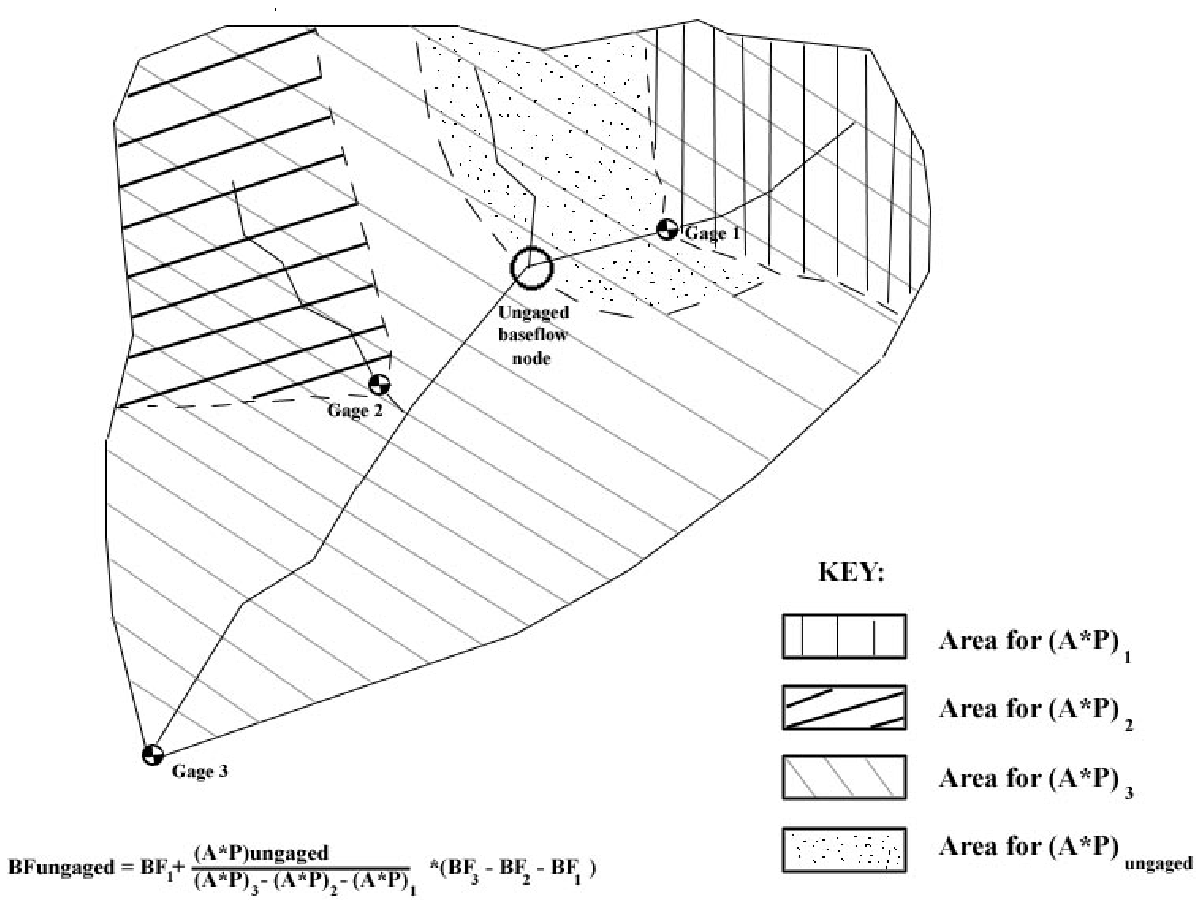


Figure 4.3 Hypothetical Basin Illustration

The portion of the baseflow gain below Gages 1 and 2 and above Gage 3, at the Ungaged location between the gages, is the gage-to-gage baseflow gain (BF_3 minus (BF_2 + BF_1)) times the ratio $(A*P)_{ungaged}/[(A*P)_{downstream\ gage} - \Sigma\ (A*P)_{upstream\ gage(s)}]$. Total baseflow at the ungaged location is equal to this term, plus the sum of baseflows at upstream gages. In the example there is only one upstream gage, having baseflow BF_1.

A second option for estimating headwater baseflows was sometimes invoked if the default method created results that did not seem credible. This method, referred to as the "neighboring gage approach", created a baseflow time series by multiplying the baseflow series at a specified gage by the ratio $(A*P)_{headwater}/(A*P)_{gage}$. This approach was effective, for example, for an ungaged tributary parallel and close to a gaged tributary.

Where to find more information

- Documentation for **makenet** describes computation of baseflow distribution parameters based on A*P, incremental A*P, and the network configuration.

4.8 Calibration Approach

Calibration is the process of simulating the river basin under historical conditions, and judiciously adjusting parameter estimates to achieve agreement between observed and simulated values of streamgages, reservoir levels, and diversions. The Yampa River model was calibrated in a two-step process described below. The issues encountered and results obtained are described in Section 7.

4.8.1 First Step Calibration

In the first calibration run, the model was executed with relatively little freedom with respect to operating rules. Headgate demand was simulated by historical diversions, and historical reservoir contents served as operational targets. The reservoirs would not fill beyond the historical content even if water was legally and physically available. Operating rules caused the reservoir to release to satisfy beneficiaries' demands, but if simulated reservoir content was higher than historical after all demand was satisfied, the reservoir released water to the river to achieve the historical end-of-month content. Had there been any multiple-headgated collection systems in the Yampa basin, the first calibration run would feature the historical diversion as the demand at each diversion point.

The objective of the first calibration run was to refine baseflow hydrology before introducing uncertainties related to rule-based operations. Diversion shortages, that is, the inability of a water right to divert what it diverted historically, indicated possible problems with the way baseflows were represented. Baseflow issues were also evidenced by poor simulation of the historical gages. Generally, the parameters that were adjusted related to the distribution of baseflows (i.e., A*P parameters or the method for distributing baseflows to ungaged locations), and locations of return flows.

4.8.2 Second Step Calibration

In the second calibration run, constraints on reservoir operations were relaxed. As in the first calibration run, reservoirs were simulated only for the period in which they were on-line historically. Reservoir storage was limited only by water right and availability, and generally, reservoir releases were controlled by downstream demands. Exceptions were made for reservoirs known to operate by power or flood control curves, or other unmodeled considerations. In these cases, targets were developed to express the operation. Had there been any multi-structures in the Yampa basin, a centralized demand would have been placed at the final destination nodes, and priorities and legal availability would govern diversions from the various headgates.

The objective of the second calibration step was to refine operational parameters. For example, poor calibration at a reservoir might indicate poor representation of administration or operating objectives. At Stagecoach Reservoir, for example, considerable effort was devoted to the interaction of a direct flow right for hydropower generation, and use of the stored supply. Calibration was evaluated by comparing simulated gageflows, reservoir contents, and diversions with historical observations of these parameters.

Where to find more information

- Section 7 of this document describes calibration of the Yampa River model.

4.9 Baseline Data Set

The Baseline data set is intended as a generic representation of recent conditions on the Yampa River, to be used for “what if” analyses. It represents one interpretation of current use, operating, and administrative conditions, as though they prevailed throughout the modeling period. All existing water resources systems are on line and operational in the model from 1909 forward, as are junior rights and modern levels of demand. The data set is a starting point, which the user may choose to add to or adapt for a given application or interpretation of probable demands and near-term conditions.

4.9.1 Calculated Irrigation Demand

In the Baseline data set, irrigation demand is set to a time series determined from crop irrigation water requirement and average irrigation efficiency for the structure. This “Calculated Demand” is an estimate of the amount of water the structure would have diverted absent physical or legal availability constraints. Thus if more water was to become available to the diverter under a proposed new regime, the model would show the irrigator with sufficient water rights diverting more than he did historically.

A preliminary monthly Calculated demand is generated by dividing the crop irrigation water requirement for each month by average monthly irrigation efficiency for the period 1950-2005. The irrigation efficiency may not exceed 0.54, however, which represents a practical upper limit on efficiency for flood irrigation systems. Thus the demand for a perennially shorted diversion (diversion divided by irrigation water requirement is, on average, greater than 0.54) will be greater than the historical diversion for at least some months.

Final Calculated demand is developed as the larger of the preliminary Calculated demand and the historical diversion for each structure and time step. This step ensures that historical practices during wet periods are preserved in the model. It also allows for winter diversions, typically to water stock, to be simulated, even though there is no crop requirement at that time of year.

4.9.2 Municipal And Industrial Demand

Municipal and industrial demands were set to recent values or averages of recent records, as recommended by the Yampa Hydrology Subcommittee of the Yampa Management Plan effort.

4.9.3 Transbasin Demand

Transbasin diversion demands were set to average monthly diversions over the period 1975-1991.

4.9.4 Reservoirs

All reservoirs are represented as being on-line throughout the study period, at their current capacities. Initial reservoir contents were set to full. During simulation, StateMod sizes reservoir releases to satisfy unmet headgate demand, assuming the reservoir is a supplemental supply to direct flow rights. (StateMod has the option of sizing releases to meet irrigation water requirement at maximum efficiency, but that style of operation is not characteristic of the Yampa River basin reservoirs.)

5. Baseline Data Set

This section describes each StateMod input file in the Baseline Data Set. The data set, described in more general terms in Section 4.9, is expected to be a starting point for users who want to apply the Yampa River water resources planning model to a particular management issue. Typically, the investigator wants to understand how the river regime would change under a new use or different operations. The change needs to be quantified relative to how the river would look today absent the new use or different operation, which may be quite different from the historical record. The Baseline data set provides a basis against which to compare future scenarios. Users may opt to modify the Baseline data set for their own interpretation of current or near-future conditions. The following detailed, file-by-file description is intended to provide enough detail that this can be done with confidence.

This section is divided into several subsections:

- Section 5.1 describes the response file, which simply lists names of the rest of the data files. The section tells briefly what is contained in each of the named files, so refer to it if you need to know where to find specific information.
- Section 5.2 describes the control file, which sets execution parameters for the run.
- Section 5.3 includes four files that together specify the river system. These files express the model network and baseflow hydrology.
- Section 5.4 includes files that define characteristics of the diversion structures in the model: physical characteristics, irrigation parameters, historical diversions, demand, and water rights.
- Section 5.5 includes files that further define irrigation parameters for diversion structures.
- Section 5.6 includes files that define characteristics of the reservoir structures in the model: physical characteristics, evaporation parameters, historical contents, operational targets, and water rights.
- Section 5.7 includes files that define characteristics of instream flow structures in the model: location, demand, and water rights.
- Section 5.8 describes the operating rights file, which specifies operations other than simple diversions, onstream reservoir storage, and instream flow reservations. For example, the file specifies rules for reservoir releases to downstream users, diversions by exchange, and movement of water from one reservoir to another.

Where to find more information

- For generic information on every input file listed below, see the StateMod documentation. It describes how input parameters are used as well as format of the files.

5.1 Response File (*.rsp)

The response file is created by hand using a text editor, and lists all the other files in the data set. StateMod reads the response file first, and then "knows" what files to open to get the rest of the input data. The list of input files is slightly different depending on whether StateMod is being run to generate baseflows or to simulate. Since the "Baseline data set" refers to a particular simulation scenario, the response file for the Baseline is presented first; it is followed by a description of the files used for baseflow generation.

5.1.1 For Baseline Simulation

The listing below shows the file names in *ym2009B.rsp*, describes contents of each file, and shows the subsection of this chapter where the file is described in more detail.

File Name	Description	Reference
ym2009.ctl	Control file – specifies execution parameters, such as run title, modeling period, options switches	Section 5.2
ym2009.rin	River network file – lists every model node and specifies connectivity of network	Section 5.3.1
ym2009B.res	Reservoir station file – lists physical reservoir characteristics such as volume, area-capacity table, and some administration parameters	Section 5.6.1
ym2009.dds	Direct diversion station file – contains parameters for each diversion structure in the model, such as diversion capacity, return flow characteristics, and irrigated acreage served	Section 5.4.1
ym2009.ris	River station file – lists model nodes, both gaged and ungaged, where hydrologic inflow enters the system	Section 5.3.2
ym2009.ifs	Instream flow station file – lists instream flow reaches	Section 5.7.1
ym2009.ifr	Instream flow right file – gives decreed amount and administration number of instream flow rights associated with instream flow reaches	Section 5.7.3
ym2009B.rer	Reservoir rights file – lists storage rights for all reservoirs	Section 5.6.5
ym2009.ddr	Direct diversion rights file – lists water rights for direct diversion	Section 5.4.5
ym2009C.opr	Operational rights file – specifies many different kinds of operations that are more complex than a direct diversion or an onstream storage right. Operational rights can specify, for example, a reservoir release for delivery to a downstream diversion point, a reservoir release to allow diversion by exchange at a point which is not downstream, or a direct diversion to fill a	Section 5.8

File Name	Description	Reference
	reservoir via a feeder	
yampaF.eva	Evaporation file – gives monthly rates for net evaporation from free water surface	Section 5.6.2
ym2009x.xbm	Baseflow data file – time series of undepleted flows at all nodes listed in *ym2009.ris*	Section 5.3.5
ym2009B.ddm	Monthly demand file – monthly time series of headgate demands for each direct diversion structure	Section 5.4.4
ym2009.ifa	Instream flow demand file – gives the decreed monthly instream flow rates	Section 5.7.2
ym2009.dly	Delay Table – contains several return flow patterns that express how much of the return flow accruing from diversions in one month reach the stream in each of the subsequent months, until the return is extinguished	Section 5.4.2
ym2009B.tar	Reservoir target file – monthly time series of maximum and minimum targets for each reservoir. A reservoir may not store above its maximum target, and may not release below the minimum target	Section 5.6.4
ym2009.ipy	Irrigation practice yearly file – maximum efficiency and irrigated acreage by year and by structure, for variable efficiency structures	Section 5.5.2
ym2009.iwr	Irrigation Water Requirement file – monthly time series of crop water requirement by structure, for variable efficiency structures	Section 5.5.3
ym2009.str	StateCU Structure file – location, assigned climate station(s), and soil moisture capacity by structure, for variable efficiency structures	Section 5.5.1
ym2009.eom	Reservoir End of month contents file – Monthly time series of historical reservoir contents	Section 5.6.3
ym2009.rib	Baseflow Parameter file – gives coefficients and related gage ID's for each baseflow node, with which StateMod computes baseflow gain at the node	Section 5.3.3
ym2009.rih	Historical streamflow file – Monthly time series of streamflows at modeled gages	Section 5.3.4
ym2009.ddh	Historical Diversions – Monthly time series of historical diversions	Section 5.4.3

5.1.2 For Generating Baseflow

The baseflow file (*.xbm) that is part of the Baseline data set was created by StateMod and the Mixed Station Model in three steps which are described in Sections 4.7.1 through 4.7.3. In the first step, StateMod estimates baseflows at gaged locations, using the files listed in the response file ym2009.rsp. When the initial baseflow run is made, the baseflow file (*.xbm) is the output. The baseflow response file calls for different reservoir station, operational rights, and reservoir target files from the Baseline response file, in all cases to reflect strictly historical data.

The baseflow time series created in the first run are all partial series, because gage data is missing some of the time for all gages. The Mixed Station Model is used to fill the series, creating a complete series of baseflows at gages in a file named ym2009.xbf. The response file for the third step, in which StateMod distributes baseflow to ungaged points, is named ym2009x.rsp. The only difference between the first-step response file ym2009.rsp and third-step response file ym2009x.rsp is that the name ym2009.xbf replaces the historical gage file ym2009.rih.

5.2 Control File (*.ctl)

The control file is hand-created using a text editor. It contains execution parameters for the model run, including starting and ending year for the simulation, the number of entries in certain files, conversion factors, and operational switches. Many of the switches relate to either debugging output, or to integrated simulation of groundwater and surface water supply sources. The latter was developed for the Rio Grande basin and is not a feature of the Yampa model. Control file switches are all specifically described in the StateMod documentation. The simulation period parameters (starting and ending year) are the ones that users most typically adjust.

5.3 River System Files

5.3.1 River Network File (*.rin)

The river network file is created by the StateDMI It describes the location and connectivity of each node in the model. Specifically, it is simply a list of each structure ID and name, along with the ID of the next structure downstream. It is an inherent characteristic of the network that, with the exception of the downstream terminal node, each node has exactly one downstream node.

Figure 4.1 in Section 4.2.1 illustrates the network, which starts at Stillwater Reservoir in the Bear River headwaters and ends at the Colorado-Utah state line. The Yampa River actually ends at its confluence with the Green River within Colorado. The network includes the confluence and one aggregated node on the Green River representing Colorado's consumptive use of mainstem Green River water.

River gage nodes are labeled with United States Geological Survey (USGS) stream gaging station numbers (i.e., 09000000). Diversion and reservoir structure identification numbers are composed of Water District number followed by the State Engineer's four-digit structure ID. Table 5.1 shows how many nodes of each type are in the Yampa model.

Table 5.1
River Network Elements

Type	Number
Diversion	290
Instream Flow	24
Reservoirs	23
Stream Gages	22
Total	359

Where to find more information

- StateDMI documentation gives the file layout and format for the *.net* file.

5.3.2 River Station File (*.ris)

The river station file is also created by StateDMI. It lists the model's baseflow nodes, both gaged and ungaged. These are the discrete locations where streamflow is added to the modeled system.

There are 22 gages in the model and 73 ungaged baseflow locations, for a total of 95 hydrologic inflows to the Yampa River model. Ungaged baseflow nodes include all ungaged headwater nodes, all key reservoir nodes, many of the aggregated diversion nodes, and any other nodes where calibration revealed a need for it. In the last case, water that was simulated as entering the system further down (e.g., at the next gage) was moved up the system to the ungaged point.

5.3.3 Baseflow Parameter File (*.rib)

The baseflow parameter file has an entry for each ungaged baseflow node in the model, specifying coefficients, or "proration factors", used to calculate the baseflow gain at that point. **StateDMI** computes proration factors based on the network structure and Area multiplied by Precipitation values supplied for both gages and ungaged baseflow nodes. This information is in the network file which is input to **StateDMI**. Under the default "gain approach", described in Section 4.7.3, the factors reflect the ratio of the product of incremental area and local average precipitation above the ungaged point to the product of incremental area and local average precipitation for the entire gage-to-gage reach.

At some locations, the hydrograph developed using the gain approached showed an attenuated shape that was not representative of a "natural" hydrograph. This occurred in headwater areas where the hydrograph is dominated by runoff from spring snowmelt. In these situations, baseflow was determined as a function of baseflow at a nearby stream gage, specified by the user. Ideally, this "neighboring gage" was from a drainage with similar physiographic characteristics. Baseflow at the ungaged site was assumed to be in the same proportion to baseflow at the nearby gage as the product of area and average precipitation at the two locations. This procedure, referred to as the "neighboring gage approach", was applied to these tributaries:

Tributary Name	Baseflow WDID	Neighboring Gage
Upper Bear River	583540	09241000
Dome Creek	582216	09241000
Coal Creek	582214	09241000
Brinker Creek	580556	09241000
Chimney Creek	58ADY_002	09241000
Watson Creek	580782	09241000
Larson Creek	580731	09241000
North Hunt Creek	580685	09241000
Mill Creek	581085	09241000
Middle Hunt Creek	583500	09237500
Walton Creek	580687	09238900
Soda Creek	582311	09238900
Sand Creek	580663	09241000
Big Creek	580640	09241000
Hot Springs Creek	580695	09241000
Smith Creek	580917	09241000
Trout Creek	571009	09241000

Tributary Name	Baseflow WDID	Neighboring Gage
W. Fish Creek	570544	09241000
Stinking Gulch	440518	09249750
Little Bear Creek	440573	09245000
Pine Creek	440611	09249750
Deer Creek	440716	09249750
Waddle Creek	440644	09249750
Morapos Creek	440572	09249750
Milk Creek	440692	09249750
Good Spring Creek	440524	09249750
Little Cottonwood Creek	440998	09245000
Muddy Creek	WYD_009	09255500
Green River	56_ADY027	09241000

Where to find more information

- Section 4.7.3 describes how baseflows are distributed spatially.

5.3.4 Historical Streamflow File (*.rih)

Created by **TSTool**, the historical streamflow file contains historical gage records for 1909 through 2005, for the modeled gages. These are used for baseflow stream generation and to create comparison output that is useful during model calibration. All records are taken directly from USGS tables in the database. Missing values, when the gage was not in operation, are denoted as such, using the value "-999."

Table 5.2 lists the gages used, their periods of record, and their average annual flows over the period of record.

Table 5.2
Historical Average Annual Flows for Modeled Yampa Stream Gages

Gage ID	Gage Name	Period of Record	Historical Flow (af/yr)
9236000	Bear River Near Toponas	1953-1965, 1967-1986	29,403
9237500	Yampa River Below Stagecoach Reservoir	1940-1944. 1957-1972, 1985-2005	59,381
9238900	Fish Creek At Upper Station	1967-1972, 1973-1979[1], 1983-2005	46,062
9239500	Yampa River At Steamboat Springs	1910-2005	332,150
9241000	Elk River At Clark	1911-1916, 1918, 1920, 1932-1991, 1998-2003[1]	237,766
9244410	Yampa River Below Diversion near Hayden	1966-1986	809,415
9245000	Elkhead Creek Near Elkhead	1953-1996	40,199
9245500	North Fork Elkhead Creek	1959-1973	12,514
9246920	Fortification Creek near Fortification	1985-1991, 2003-2005	7,588
9247600	Yampa River Below Craig	1985-2005	887,401
9249000	East Fork Of Williams Fork	1954-1971	81,571
9249200	South Fork Of Williams Fork	1966-1979	30,635
9249750	Williams Fork At Mouth	1985-2001	157,476
9251000	Yampa River Near Maybell	1916-2005	1,121,764
9253000	Little Snake River Near Slater	1944-1947, 1951-1999,2002-2005	163,649
9255000	Slater Fork Near Slater	1932-2005	56,021
9255500	Savery Creek at Upper Station near Savery	1941,1953-1998	36,470
9256000	Savery Creek near Savery	1942-1946,1948-1998	80,651
9257000	Little Snake River near Dixon	1911-1923,1939-1998	376,476
9258000	Willow Creek Near Dixon	1954-1992	7,380
9260000	Little Snake River Near Lily	1922-2005	409,314
9260050	Yampa River At Deerlodge Park	1983-1994, 1997-2005	1,490,492

[1] Summer records only.

5.3.5 Baseflow Files (*.xbm)

The baseflow file contains estimates of base streamflows throughout the modeling period, at the locations listed in the river station file. Baseflows represent the conditions upon which simulated diversion, reservoir, and minimum streamflow demands are superimposed. StateMod estimates baseflows at stream gages, during the gage's period of record, from historical streamflows, diversions, end-of-month contents of modeled reservoirs, and estimated consumption and return flow patterns. It then distributes baseflow at gage sites to ungaged locations using proration factors representing the fraction of the reach gain estimated to be tributary to a baseflow point.

Table 5.3 compares historical gage flows with simulated baseflows for the four gages that operated throughout the calibration period (1975-2005). The difference between the two represents an estimate of historical consumption over this period.

Table 5.3
Streamflow Comparison (1975-2005 Average in af/yr)

Gage ID	Gage Name	Baseflow	Historical	Difference
09239500	Yampa River at Steamboat Springs	362,739.	316,785	45,955
09251000	Yampa River near Maybell	1,272,186	1,111,651	160,536
09255000	Slater Fork near Slater	64,863	59,834	5,029
09260000	Little Snake River near Lily	468,549	396,915	71,635

Where to find more information

- Sections 4.7.1 through 4.7.3 explain how StateMod and the Mixed Station Model are used to create baseflows.
- When StateMod is executed to estimate baseflows at gages, it creates a Baseflow Information file *(*.xbi*) that shows this computation for each gage and each month of the time step.
- When the Mixed Station Model is used to fill baseflows, it creates two reports, *ym2009.sum* and *ym2009.sts*. The first indicates which stations were used to estimate each missing data point, and the second compares statistics of the unfilled time series with statistics of the filled series for each gage.

5.4 Diversion Files

5.4.1 Direct Diversion Station File (*.dds)

StateDMI creates the direct diversion station file. The direct diversion station file describes the physical properties of each diversion simulated in the Yampa Model. Table 5.4 is a summary of the Yampa River model's diversion station file contents, including each structure's diversion capacity, irrigated acreage served, and average annual system efficiency. The table also includes average annual headgate demand. This parameter is summarized from data in the diversion demand file rather than the diversion station file, but it is included here as an important characteristic of each diversion station. In addition to the tabulated parameters, the file also specifies return flow nodes and average monthly efficiencies.

Generally, the diversion station ID and name, diversion capacity, and irrigated acreage are gathered from Hydrobase by **StateDMI**. Return flow locations are specified to **StateDMI** in a hand-edited file ym2009.rtn. The return flow distribution was based on discussions with Division 6 personnel as well as calibration efforts. **StateCU** computes monthly system efficiency from historical diversions and historical crop irrigation requirements for irrigation structures, and **StateDMI** writes the average monthly efficiencies into the *.dds file. For non-irrigation structures, monthly efficiency is specified by the user as input to **StateDMI**. Each of the parameters is described in more detail following Table 5.4.

Table 5.4
Direct Flow Diversion Summary
1975-2005

#	Model ID#	Name	Cap (cfs)	Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
1	440509	WILSON DITCH	17	187	49	1,428
2	440511	WISCONSIN DITCH	32	543	51	3,320
3	440514	WOOLEY & JOHNSON D	9	129	48	742
4	440517	YAMPA VAL STOCK BR CO D	18	598	52	2,215
5	440518	YELLOW JACKET DITCH NO 1	21	150	54	667
6	440522[2]	CRAIG STATION D & PL #1	45	0	100	12,060
7	440524	AQ DITCH 1	5	5	32	232
8	440527	AIR LINE IRR D	999	127	43	728
9	440533	ANDERSON DITCH	5	64	52	340
10	440541	BAILEY DITCH	16	97	35	1,117
11	440570	CARD DITCH	18	182	45	1,488
12	440572	CARRIGAN-AVERILL D	11	46	42	276
13	440573	CATARACT DITCH	21	659	54	2,885
14	440581[2]	CRAIG WATER SUPPLY PL	15	800	36	2,200
15	440583	CROSS MTN PUMP - GROUNDS	26	463	40	3,437
16	440584	CROSS MTN PUMP NO 1 & 2	25	385	43	3,251
17	440585	CRYSTAL CK DITCH	6	30	44	462
18	440586	D D & E DITCH	51	631	50	3,493
19	440587	D D FERGUSON D NO 2	30	514	53	2,615
20	440589	DEEP CUT IRR D	69	583	37	6,497
21	440590	DEER CK & MORAPOS D	27	240	48	1,740
22	440593	DENNISON & MARTIN D	11	222	54	1,023
23	440601	DUNSTON DITCH	10	40	33	854
24	440607	EGRY MESA DITCH	23	357	36	3,649
25	440611	ELK TRAIL DITCH	19	223	52	1,233
26	440612	ELKHORN IRR DITCH	20	235	53	1,315
27	440613	ELLGEN DITCH	8	210	54	695
28	440614	ELLIS & KITCHENS D	8	27	42	331
29	440628	GIBBONS WILSON JORDAN D	10	128	53	726
30	440635	GRIESER DITCH	8	95	51	562
31	440638	HADDEN BASE DITCH	15	206	54	998
32	440644	HARPER DITCH 1	8	187	54	842
33	440645	HARPER DITCH 2	8	31	48	299
34	440647	HAUGHEY IRR DITCH	14	239	53	1,300
35	440650	HIGHLINE MESA BAKER D	11	146	80	341
36	440651	HIGHLAND DITCH	16	856	54	3,186
37	440652	HIGHLAND AKA HIGHLINE D	14	147	43	1,163

#	Model ID#	Name	Cap (cfs)	Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
38	440660	J A MARTIN DITCH	12	96	46	705
39	440661	J P MORIN DITCH	10	125	49	735
40	440675	JUNIPER MTN TUNNEL	68	503	36	4,812
41	440677	K DIAMOND DITCH	21	462	61	2,199
42	440681	LAMB IRR DITCH	9	63	46	497
43	440687	LILY PARK PUMP NO 1	999	557	49	3,080
44	440688	LITTLE BEAR DITCH	23	636	70	2,140
45	440691	M DITCH	15	106	36	1,343
46	440692	MARTIN CK DITCH	62	374	47	3,027
47	440694	MAYBELL CANAL	129	1,183	33	16,539
48	440695[2]	MAYBELL MILL PIPELINE	2	0	100	350
49	440698	MCDONALD DITCH	12	100	52	636
50	440699	MCKINLAY DITCH NO 1	27	196	50	1,235
51	440700	MCKINLAY DITCH NO 2	30	414	51	2,211
52	440702	MCINTYRE DITCH	20	159	31	2,406
53	440706	MILK CK DITCH	28	374	51	1,525
54	440711	MOCK DITCH	12	168	48	1,116
55	440716	MULLEN DITCH	6	129	53	531
56	440723	NICHOLS DITCH NO 1	7	124	39	1,129
57	440724	NORVELL DITCH	30	393	49	2,400
58	440729	PATRICK SWEENEY D	15	195	39	2,261
59	440731	PECK IRRIG D	20	199	43	1,486
60	440735	PINE CK DITCH	12	169	52	898
61	440740	RATCLIFF DITCH	11	41	40	746
62	440747	ROBY D AKA ROBY D NO 1	7	201	54	889
63	440748	ROBY DITCH NO 2	16	110	52	558
64	440749	ROUND BOTTOM D NO 1	7	30	43	265
65	440750	ROUND BOTTOM D NO 2	9	35	42	389
66	440751	ROUND BOTTOM DITCH	12	144	45	679
67	440763	SMITH DITCH	21	340	49	1,723
68	440770	STARR IRRIG DITCH	9	26	43	291
69	440778	SUNBEAM DITCH	10	129	33	1,783
70	440785	TIPTON IRR DITCH	17	289	54	1,456
71	440786	TISDEL D NO 2	15	356	46	2,025
72	440790	UTLEY DITCH	13	75	33	1,280
73	440801	CROSS MTN PUMP - GUESS	9	47	28	1,401
74	440806	ELLGEN NO 2 DITCH	10	86	52	418
75	440812	HART DITCH	16	88	52	559
76	440814	HIGHLINE DITCH	12	145	49	776
77	440820	LOWRY SEELEY PUMP	11	284	47	1,592

#	Model ID#	Name	Cap (cfs)	Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
78	440821	MACK DITCH	8	119	52	559
79	440830	OLD SWEENEY DITCH	14	149	39	1,712
80	440863	HENRY SWEENEY DITCH	13	163	37	1,960
81	440998	DRY COTTONWOOD DITCH 1	9	107	51	591
82	441122	VAUGHN PUMP	25	271	32	2,698
83	442214	WISE DITCH ALT PT	999	171	54	541
84	44_ADY012	ADY012_ElkheadCreek	60	639	56	2,848
85	44_ADY013	ADY013_YampaRbelCraig	469	1,787	58	6,222
86	44_ADY014	ADY014_EFkWilliamsFork	61	1,818	54	8,584
87	44_ADY015	ADY015_SFkWilliamsFork	54	768	51	4,807
88	44_ADY016	ADY016_WilliamsFork	201	1,588	57	7,511
89	44_ADY017	ADY017_MilkCrabvGSpring	22	517	54	2,340
90	44_ADY018	ADY018_MilkCreek	43	1,104	53	4,025
91	44_ADY019	ADY019_YampaRnrMaybell	292	1,039	51	4,599
92	44_ADY025	ADY025_YampaR@DeerLodge	54	701	38	4,834
93	44_AMY001[2]	44_AMY001_YampaRbelCraig	999	0	100	742
94	44_FDP001	44_FDP_WD_44	999	0	36	0
95	44_WSA	44_WSA_EDFdemand	999	0	0	0
96	540507	BEELER DITCH	16	139	43	1,586
97	540531	HEELEY DITCH	35	1,249	54	4,495
98	540532	HOME SUPPLY DITCH	15	159	46	1,531
99	540543	LUCHINGER DITCH	12	101	43	1,165
100	540548	MORGAN & BEELER D	18	205	41	1,775
101	540549	MORGAN SLATER DITCH	10	148	48	1,056
102	540554	PERKINS FOX DITCH	14	447	54	2,043
103	540555	PERKINS IRR DITCH	19	497	51	2,540
104	540564	SALISBURY DITCH	7	51	39	746
105	540568	SLATER FORK DITCH	16	226	47	1,398
106	540570	SLATER PARK DITCH NO 1	12	387	54	1,786
107	540571	SLATER PARK DITCH NO 2	5	101	53	537
108	540574	SLAT_SLATER PARK DIT	19	241	52	1,409
109	540583	TROWEL DITCH	72	759	46	5,625
110	540591	WILLOW CK DITCH	22	696	53	3,514
111	540592	WILSON DITCH	7	61	43	526
112	540594	WOODBURY DITCH	23	430	50	1,694
113	54_ADY020	ADY020_LSnakeRnrSlater	92	1,757	53	9,504
114	54_ADY021	ADY021_LSnakeRabvSlater	64	1,015	51	6,579
115	54_ADY022	ADY022_SlaterCreek	98	1,686	56	8,714
116	54_ADY023	ADY023_LSnakeabvDryGlch	326	4,327	44	41,424
117	550504	ESCALANTA PUMP 2	999	101	40	1,154

#	Model ID#	Name	Cap (cfs)	Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
118	550506	MAJORS PUMP NO 2	19	388	46	2,542
119	550507	NINE MILE IRR DITCH	13	91	37	1,171
120	550508	NINE MILE IRR PL	7	73	36	990
121	550513	VISINTAINER DITCH	13	69	37	839
122	550519	RINKER PUMP D	12	64	43	896
123	550537	LEFEVRE NO 1 PUMP	11	342	46	1,958
124	55_ADY024	ADY024_LSnakeRnrLily	33	552	38	5,225
125	55_ADY026	ADY026_YampaR@GreenR	7	108	37	821
126	55_AMY003[2]	55_AMY003_LSnakeRnrLily	999	0	100	13
127	55_FDP001	Fu_Dev_55	999	0	16	0
128	56_ADY027	ADY027_GreenRiver	130	2,173	47	11,443
129	56_FDP001	Fu_Dev_56	999	0	16	0
130	570508	BROCK DITCH	37	419	41	3,088
131	570510	CARY DITCH CO DITCH	38	746	43	4,233
132	570512[2]	COLO UTILITIES D & PL	30	0	100	4,887
133	570517	DAVID M CHAPMAN DITCH	5	115	47	845
134	570519	DENNIS & BLEWITT D	15	239	49	1,202
135	570524	EAST SIDE DITCH	10	122	51	694
136	570525	EAST SIDE DITCH 2	11	191	53	917
137	570535	ERWIN IRRIGATING DITCH	6	62	35	589
138	570539	GIBRALTAR DITCH	80	1,079	40	7,624
139	570544	HIGHLAND DITCH	17	387	54	1,668
140	570545	HOMESTEAD DITCH	16	229	50	1,435
141	570555	LAST CHANCE DITCH	19	166	43	1,202
142	570561	MALE MOORE CO DITCH	13	29	37	550
143	570563	MARSHALL ROBERTS DITCH	38	541	34	4,164
144	570576	ORNO DITCH	9	140	48	781
145	570579	R E CLARK DITCH	14	156	45	1,048
146	570584	SADDLE MOUNTAIN DITCH	11	102	48	841
147	570592	SHELTON DITCH	56	1,110	35	8,125
148	570608	TROUT CREEK DITCH 3	19	295	50	1,539
149	570609	TROUT CREEK DITCH 2	9	56	42	468
150	570611	WALKER IRRIG DITCH	48	1,298	43	6,517
151	570622	WILLIAMS IRRIG DITCH	22	288	37	2,854
152	570623	WILLIAMS PARK DITCH	30	283	53	1,295
153	570635	KOLL DITCH	15	164	44	1,358
154	574629[1]	RICH DITCH	19	0	0	1,469
155	57_ADY009	ADY009_TroutCreek	104	920	50	4,727
156	57_ADY010	ADY010_YampaRnrHayden	124	369	49	2,133
157	57_ADY011	ADY011_YampaRabvElkhead	118	1,035	58	3,490

#	Model ID#	Name	Cap (cfs)	Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
158	57_AMY001[2]	57_AMY001_YampaRabCraig	999	0	100	484
159	57_FDP001	Fu_Dev_57	999	0	33	0
160	57_NAG01	Nu_Ag_Dev	999	0	19	0
161	57_NMID01	Nu_Fu_M&I	999	0	36	0
162	57_NPWR01	Nu_Fu_Pwr	999	0	100	0
163	580500	ACTON D	19	266	46	1,894
164	580506[1]	ALLEN BASIN SUPPLY D	60	0	0	187
165	580508	ALPHA DITCH	18	310	52	1,532
166	580530	BAXTER DITCH	50	585	49	3,188
167	580532	BEAVER CREEK D	8	133	49	658
168	580539	BIG MESA DITCH	39	805	49	5,372
169	580541	BIRD DITCH	17	440	53	2,083
170	580556	BRINKER CREEK DITCH	6	89	47	521
171	580559	BROOKS DITCH	12	130	48	855
172	580561	BRUMBACK DITCH	5	64	46	478
173	580564	BUCKINGHAM MANDALL D	24	698	52	3,399
174	580568	BURNETT DITCH	20	325	46	1,897
175	580569	BURNT MESA D	14	125	51	585
176	580574	C R BROWN MOFFAT COAL D	7	79	48	444
177	580577	CAMPBELL DITCH	17	324	52	1,635
178	580582	CHARLES & A LEIGHTON D	6	32	35	540
179	580583	CHARLES H KEMMER D	7	6	27	312
180	580588	CLARK & BURKE DITCH	10	158	47	960
181	580590	COLEMAN DITCH	7	160	54	630
182	580591	COLLINS DITCH	9	183	50	995
183	580599	CULLEN DITCH 2	10	68	58	818
184	580604	DAY DITCH	10	190	54	743
185	580612	DEVER D	11	117	47	773
186	580618	DUQUETTE DITCH	20	234	42	1,969
187	580622	EGERIA DITCH	17	274	46	1,988
188	580623	EKHART DITCH	16	160	45	1,383
189	580626	ELK VALLEY DITCH CO. D.	50	441	46	3,452
190	580627	ENTERPRISE DITCH	30	581	48	3,188
191	580628	EXCELSIOR DITCH	13	96	45	643
192	580633	FELIX BORGHI DITCH	18	105	35	1,355
193	580634	FERGUSON DITCH	16	195	48	1,233
194	580640	FIRST CHANCE DITCH	10	74	39	691
195	580642[2]	FISH CR MUN WATER INTAKE	19	0	36	2,913
196	580643	FIX DITCH	18	499	54	2,156
197	580649	FRANZ DITCH	24	575	52	2,823

#	Model ID#	Name	Cap (cfs)	Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
198	580662	GRAHAM & BENNETT D	20	384	47	2,505
199	580663	GREER DITCH	8	184	51	892
200	580665	GUIDO DITCH	11	90	49	429
201	580684	HERNAGE & KOLBE DITCH	9	111	36	1,131
202	580685	HIGH MESA IRR D	7	160	51	648
203	580687	HIGHLINE BEAVER DITCH	13	111	45	685
204	580694	HOOVER JACQUES DITCH	26	474	46	2,774
205	580695	HOT SPGS CR HIGHLINE D	12	96	40	835
206	580714	KELLER DITCH	32	598	50	3,044
207	580717	KINNEY DITCH	10	222	48	1,384
208	580721	L L WILSON D	6	71	47	578
209	580722	LAFON DITCH	7	125	50	614
210	580728	LARSON DITCH	31	199	52	1,016
211	580730	LATERAL A DITCH	12	290	54	1,173
212	580731	LAUGHLIN DITCH	7	62	50	412
213	580738	LINDSEY DITCH	11	563	54	2,252
214	580749	LOWER PLEASANT VALLEY D	17	83	42	762
215	580756	LYON DITCH 2	13	71	47	585
216	580763	MANDALL DITCH	50	697	45	5,107
217	580767	MAYFLOWER DITCH	6	70	45	497
218	580777	MILL DITCH 1	15	102	44	608
219	580782	MOODY DITCH	8	118	52	539
220	580783	MORIN DITCH	24	463	47	3,433
221	580798	NICKELL DITCH	12	284	53	1,330
222	580801	NORTH HUNT CREEK DITCH	9	131	53	575
223	580805	OAK CREEK DITCH	12	138	48	883
224	580807	OAK DALE DITCH	10	108	47	762
225	580808	OAKTON DITCH	20	147	46	1,312
226	580809	OLD CABIN DITCH	6	89	49	449
227	580811	OLIGARCHY DITCH	5	91	48	512
228	580813	PALISADE DITCH	6	63	43	591
229	580821	PENNSYLVANIA DITCH	13	177	40	1,738
230	580826	PONY CREEK D	8	104	52	549
231	580830	PRIEST DITCH	6	34	45	292
232	580844	SAGE HEN DITCH	6	66	43	541
233	580847	SAND CREEK DITCH	9	157	53	674
234	580863	SIMON DITCH	16	586	54	2,498
235	580866	SNOW BANK DITCH	10	166	52	937
236	580868	SODA CREEK DITCH	28	330	44	2,313
237	580872	SOUTH SIDE DITCH	6	101	47	790

#	Model ID#	Name	Cap (cfs)	Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
238	580879	STAFFORD DITCH	28	250	43	2,963
239	580895	SUNNYSIDE DITCH 1	14	148	41	1,247
240	580897	SUTTLE DITCH	47	692	48	3,882
241	580908	TRULL MORIN DITCH	7	125	48	739
242	580914	UNION DITCH	999	56	28	1,936
243	580915	UPPER ELK RIVER D CO. D	15	130	44	1,250
244	580916	UPPER PLEASANT VALLEY D	17	270	50	1,619
245	580917	VAIL SAVAGE DITCH	9	168	54	757
246	580920	WALTON CREEK DITCH	73	1,641	42	11,076
247	580922	WEISKOPF DITCH	8	77	36	765
248	580924	WELCH & MONSON D	7	21	33	567
249	580928	WHEELER BROS DITCH	10	114	50	675
250	580933	WHIPPLE DITCH	12	128	45	854
251	580939	WINDSOR DITCH	6	31	39	489
252	580943	WOODCHUCK D SODA CK HG	15	371	54	1,464
253	580944	WOOLERY DITCH	37	469	44	3,047
254	580945	WOOLEY DITCH	17	318	51	1,512
255	580980	GABIOUD DITCH	5	136	51	686
256	581021	LEE IRRIGATION D	12	94	43	1,057
257	581035	NORTH SIDE DITCH	6	68	48	648
258	581074	ROSSI HIGHLINE DITCH	8	74	46	617
259	581085	MILL CREEK DITCH	17	131	52	665
260	581583[2]	STAGECOACH HYDROELECTRIC	123	0	0	52,583
261	582374[2]	STEAMBOAT SKI SNOW PL	8	0	80	373
262	584630[3]	Dome_Creek_Ditch	5	0	100	327
263	584684[3]	SARVIS DITCH	43	0	100	792
264	584685	STILLWATER DITCH	40	2,759	54	4,232
265	584686[3]	Stillwater_Colo	20	0	100	1,797
266	58_ADY001	ADY001_UpperBearRiver	61	527	44	4,294
267	58_ADY002	ADY002_ChimneyCreek	41	736	50	4,095
268	58_ADY003	ADY003_BearRabvHuntCk	510	1,292	52	6,227
269	58_ADY004	ADY004_BearRabvStagecoa	103	874	52	4,497
270	58_ADY005	ADY005_YampaRabvSteambt	219	1,488	51	8,101
271	58_ADY006	ADY006_ElkRivernrClark	33	623	53	2,872
272	58_ADY007	ADY007_MiddleElkRiver	124	2,633	54	10,279
273	58_ADY008	ADY008_LowerElkRiver	250	1,476	51	7,540
274	58_AMY001	58_AMY001_Yampa@Steamboa	999	0	100	1,342
275	58_FDP001	Fu_Dev_58	999	0	23	0
276	990528	Cheyenne_City	999	0	100	14,400

#	Model ID#	Name	Cap (cfs)	Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
277	990538	New_Wyo_Ag	999	0	25	0
278	990539	WY_First_Mesa_Canal	999	2,519	28	16,205
279	990540	WY_Westside_Canal	999	3,491	28	24,099
280	WYD_001	WY_Divs_blw_Slater_Creek	999	272	39	1,327
281	WYD_002	WY_Divs_abv_High_Savery	999	160	39	780
282	WYD_003	WY_Divs_blw_High_Savery	999	313	39	1,524
283	WYD_004	WY_Divs_btwn_gages_Svery	999	332	39	1,622
284	WYD_005	WY_Divs_lower_SaveryCrk	999	1,364	39	6,656
285	WYD_006	WY_Divs_blw_SaveryCreek	999	297	39	1,449
286	WYD_007	WY_Divs_blw_WillowCreek	999	2,288	39	11,166
287	WYD_008	WY_Baggs&Dixon	999	0	74	115
288	WYD_009	WY_Divs_Muddy_Creek	999	538	39	3,044
289	WYD_010	WY_Divs_blw_Muddy_Creek	999	306	39	1,732
290	WYD_011	WY_Divs_abv_StateLine	999	950	39	5,377

[1] Carrier ditch or feeder ditch to a reservoir
[2] Municipal/industrial diversion
[3] Transbasin diversion

5.4.1.1 Key Structures

Key diversion structures are those that are modeled explicitly, that is, the node associated with a key structure represents that single structure only. In the Yampa basin, diversion structures with water rights totaling 5 cfs or more were designated key structures. They are identified by a six-digit number which is a combination of water district number and structure ID from the State Engineer's structure and water rights tabulations. Structures in Wyoming were assigned ID's beginning with "99", with the following four digits being arbitrary.

The majority of diversion structures in the Yampa basin are for irrigation, although these exceptions divert to non-irrigation use:

WDID	Name	Diversion Type
440522	Craig Station Ditch & Pipeline	Industrial
440581	Craig Water Supply Pipeline	Municipal
440695	Maybell Mill Pipeline	Industrial
570512	Colorado Utilities Ditch and Pipeline	Industrial
574629	Rich Ditch	Trans-tributary carrier
580506	Allen Basin Supply Ditch	Trans-tributary reservoir feeder
580642	Fish Creek Municipal Water Intake	Municipal
581583	Stagecoach Hydroelectric	Industrial
582374	Steamboat Ski Snowmaking Pipeline	Industrial
584630	Dome Creek Ditch	Transbasin diverter
584684	Sarvis Ditch	Transbasin diverter
584686	Stillwater Colorado	Transbasin diverter
990528	Cheyenne_City	Municipal, transbasin diverter
WYD_008	Baggs & Dixon	Municipal

Average historical monthly efficiencies for each irrigation structure appear in the diversion station file; however, when StateMod operates in the “variable efficiency” mode, the values are not used during simulation.

For municipal, industrial, and transbasin diverters, StateMod uses the efficiencies in the diversion station file directly during simulation to compute consumption and return flows. Diversion efficiency is set to values consistent with the type of use based on engineering judgment or, if available, user information. For example, the Steamboat snowmaking diversion is assigned an efficiency of 80 percent, a value accepted in decrees and supported by industry research. Municipal diversions are assigned efficiencies that vary by month, reflecting indoor use in winter and a blend of indoor and outdoor use in the summer. Diversions for cooling water (Craig Station Ditch and Pipeline and Colorado Utilities Ditch and Pipeline) were assigned an efficiency of 100 percent, as there are no returns. This is also the case for the Maybell Mill and pipeline, as confirmed in basin meetings early in the CDSS project. The two carrier ditches, the Allen Basin Supply Ditch and Rich Ditch, are zero percent efficient, meaning their diversions are delivered without loss. All transbasin diversions are modeled as 100 percent efficient because there are no return flows to the basin.

Diversion capacity is stored in Hydrobase for most structures and is generally taken directly from the database. In preparing this file, however, the DMI’s determine whether historical records of diversion indicate diversions greater than the database capacity. If so, the diversion capacity is modified to reflect the recorded diversion. Diversion capacities for Wyoming structures were not available, and were therefore set to a high, non-limiting value.

Return flow parameters in the diversion station file specify the nodes at which return flows will re-enter the stream system, and divide the returns among several locations as appropriate. The locations were determined primarily on a case-by-case basis from topography and from conversations with water commissioners and users. The Rich Ditch (574629), which takes water from Trout Creek and delivers it to the Oak Creek basin for general use by several diverters, has been assigned a return flow location of Alpha Ditch, on Oak Creek (580508).

Where to find more information

- When StateMod is executed in the "data check" mode, it generates an *.xtb file which contains summary tables of input. One of these gives the return flow locations and percent of return flow to each location, for every diversion structure in the model.
- Section 4.2.2.1 describes how key structures were selected.
- Section 4.5 describes the variable efficiency approach for irrigation structures, and describes how diversions, consumptive use, and efficiency interact in the model for different types of structures.

5.4.1.2 Aggregate Structures

Small structures within specific sub-basins were combined and represented at aggregated nodes. Aggregated irrigation structures in Colorado were given the identifiers "wd_ADYxxx", where "wd" is the Water District number, and "ADY" stands for Aggregated Diversion Yampa; the "xxx" ranged from 001 to 027. Similarly, aggregated municipal and industrial structures were named "WD_AMYxxx" for Aggregated Municipal Yampa. Wyoming aggregated structures are designated 'WYD_xxx."

In some instances, the irrigated lands mapping yielded a different total irrigated area for aggregates, compared with the sum of irrigated acreage for individual small structures in the diversion structure database. These differences were generally minor, and the model reflects the GIS irrigated lands shape-file values, rather than the Hydrobase values.

For aggregated M&I diversions, efficiency was set to 100 percent because demands were modeled as depletions.

Where to find more information

- Section 4.2.2.2 describes how small irrigation structures were aggregated into larger structures

5.4.1.3 Special Structures

5.4.1.3.1 Stillwater Ditch

Stillwater Ditch is represented with two separate diversion structures, 584685 and 584686, because it irrigates lands in the Colorado basin as well as lands within the Yampa basin. During the Division 6 basin meetings early in the CDSS process, the ditch service area was described as having 68 percent in the Yampa basin and 32 percent in the Colorado basin. According to the CDSS irrigated land mapping, total acreage served by the ditch is 3826 acres. Accordingly, structure 584685 has been assigned 2602 acres and operates as a typical irrigation diversion. Structure 584686 is modeled as a transbasin diverter, returning no diversions to the stream. Water rights, historical diversions, and demand for the Stillwater Ditch have been split between the two structures in approximately the same ratio.

5.4.3.1.2 Wyoming Historical Diversion Structures

Historical use in Wyoming was represented by fourteen nodes: 1) one for the City of Cheyenne's diversions from the headwaters of the North Fork of the Little Snake River, 2) ten irrigation structures, each representing a known amount of irrigated acreage but an unknown number of ditches, 3) one diversion representing M&I use of Baggs and Dixon combined, and 4) two explicitly modeled irrigation structures, the Westside Canal and First Mesa Canal. This representation was adopted from the GRBP spreadsheet model, which is the source of most of the data in the diversion station file for these structures. For example, irrigated acreage, monthly efficiency for explicitly modeled irrigation structures, and return flow locations for explicitly modeled structures were taken from the GRBP.

Under the GRBP modeling effort, aggregates diverted only their depletive amounts, and it was assumed that they were perennially water short in July, August, and September. These assumptions had to be made because there were no diversion records for most ditches. Therefore, for the CDSS model, average monthly irrigation efficiencies for District 54 in Colorado were adopted for May, June, and July. August, September, and October efficiencies were set to 55 percent, the maximum efficiency cited in the GRBP.

Monthly efficiencies for the municipal use node were based on average monthly depletions by Baggs and Dixon, which were estimated as part of the Basin Use Profile section of the GRBP. It was stated that Baggs returned 41.8 percent of its municipal diversions on an annual basis, and Dixon returned none of its diversions. The monthly efficiencies assumed in the CDSS model are simply weighted by the depletion amount for each municipality and do not necessarily reflect seasonal, indoor and outdoor use.

Diversion capacities were not available from the GRBP, and were therefore set to a large, non-limiting value.

5.4.1.3.3 Future Use Diversion Structures

Several diversion stations in the network are “placeholders” for modeling the Yampa Management Plan under current and future conditions. Strictly speaking, they are not part of the Baseline data set, and are disabled in this data set. For example, demands are set to zero or rights are either absent or turned off. The diversion stations that fall into this category, and their potential configurations, are:

44_WSA – a nonconsumptive diversion that drives releases from Steamboat Lake and Elkhead Reservoir when the minimum flow requirement per the Yampa Management Plan is not being met.

44_FDP001, 55_FDP001, 56_FDP001, 57_FDP001, and 58_FDP001 – future depletions in Water Districts 44, 55, 56, 57, and 58, per the Yampa Valley Water Demand Study (BBC Research & Consulting, 1998), that would be covered by the PBO.

57_NPWR01, 57_NMID01, and 57_NAG0 – future power, M&I, and irrigation demands above and beyond the 50,000 af that the PBO covers.

990538 – future irrigation use in the Wyoming portion of the Little Snake basin

5.4.2 Return Flow Delay Tables (*.dly)

The ym2009.dly file, which is hand-built with a text editor, describes the estimated re-entry of return flows into the river system. Each table gives the percent of the return flow generated by month n’s diversion, that reaches the stream in month n, month n+1, month n+2, etc. until extinction of the return. The file contains 10 patterns, some of which are intended for use in other CDSS basins and are not used in the Yampa model.

Irrigation return patterns are based on Glover analysis for generalized characteristics of the alluvium and an assumed distance from the recharge area to the stream. The Glover patterns were then adjusted to reflect incidental loss of return flows. Two irrigation patterns have been used in the Yampa model, one that incorporates 3 percent incidental loss (Pattern 1), and one that incorporates 7 percent incidental loss in the first month and 3 percent incidental loss in the second month (Pattern 10). In all cases, these lag times represent the combined impact of surface and subsurface returns. Pattern 1 is used predominantly in the Yampa model; Pattern 10 is used only in the Little Snake River basin below Baggs.

Pattern 4 represents immediate returns, as for municipal and industrial uses. Pattern 5 is applicable to snowmaking diversions. The return patterns used in the Yampa model are shown below in Table 5.5.

Table 5.5
Percent of Return Flow Entering Stream in Months Following Diversion

Month n	Pattern 1	Pattern 4	Pattern 5	Pattern 10
1	75.6	100	0	71.6
2	11.3	0	0	8.3
3	3.2	0	0	3.2
4	2.2	0	0	2.2
5	1.6	0	100	1.6
6	1.2	0	0	1.2
7	0.8	0	0	0.8
8	0.6	0	0	0.6
9	0.5	0	0	0.5
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
Total	97	100	100	90
Note: month 1 is the same month as the diversion				

Where to find more information

- Section 4.6.1 describes how irrigation return flow delay patterns were developed.

5.4.3 Historical Diversion File (*.ddh)

The historical diversion file contains time series of diversions for each structure. The file is created by **StateDMI**, which reads historical diversions from Hydrobase and fills missing records as described in Section 4.4.2. The file is used by StateMod for baseflow estimations at stream gage locations, and for comparison output that is useful during calibration.

The file is also referenced by **StateCU** when developing average efficiency values for the diversion station file; and by **StateDMI** when developing headgate demand time series for the diversion demand file.

5.4.3.1 Key Structures

For most explicitly modeled irrigation and M&I structures, **StateDMI** accesses the CDSS database for historical diversion records. For certain structures, the data was assembled from other sources and placed into an ".stm file" which **StateDMI** can be directed to read. These cases are described below under "Special Structures".

5.4.3.2 Aggregate Structures

Aggregated irrigation diversion structures are assigned the sum of the constituent structures' historical diversion records from the database.

Four nodes in the model represent the combined small diversions for municipal, industrial, and livestock use in four water districts in the basin. These structures are modeled as diverting only the depletive portion of their diversions, and consuming all of it. Thus estimated historical diversions are equivalent to estimated consumptive use. Total non-irrigation consumptive use in the Yampa basin was estimated relatively early in CDSS development, as documented in the memorandum "Consumptive Use Model Non-Irrigation Consumptive Uses and Losses in the Yampa River Basin." Consumptive use of the key municipal and industrial diversions in the model was subtracted from this basinwide M&I consumption, to derive the basinwide consumptive use attributable to small M&I users. This value was distributed to Water Districts 44, 55, 57, and 58 in accordance with a general distribution of M&I use identified by BBC Research in their 1998 "Yampa Valley Water Demand Study."

The use is the same each year of the study.

5.4.3.3 Special Structures

5.4.3.3.1 Stillwater Ditch

Diversion time series for the two nodes representing the Stillwater Ditch were created outside **StateDMI** by splitting the database diversions, with approximately 70 percent being assigned to the Yampa basin node, and 30 percent being assigned to the Colorado basin node. The split is based on irrigated acreage on either side of the drainage divide.

5.4.3.2.2 Wyoming Historical Diversion Structures

Diversion time series for Cheyenne (990528), First Mesa Canal (990539), and Westside Canal (990540) were obtained via the GRBP. The GRBP model study period was 1971-1998, and the data was limited to this period or less. Cheyenne diversions were available for the entire 28 years. The irrigation diversions were available for 1983 through 1998 only. However, all years from 1971-1998 were classified in the GRBP study as being Normal, Wet, or Dry, and an annual cycle of diversions representing each of those conditions had been developed. Thus years 1971 through 1982 were filled with the Normal, Wet, or Dry diversions as appropriate.

Historical diversions for Wyoming aggregate structures (WYD_001 through WYD_011) were "built" by dividing the irrigation water requirement for the month by an assumed monthly efficiency, and adjusting for the small number of irrigation days in August and September. Irrigation water requirement had been estimated in the GRBP model for Normal, Wet, and Dry years for these structures. Historical efficiency was difficult to estimate, however, given the lack of diversion records. The GRBP spreadsheets circumvented the data limitation by modeling only the consumptive depletion. According to the GRBP, First Mesa Canal and Westside Canal – the only structures with good diversion records and reliable estimates of irrigated acreage – were not representative of the water-short conditions that most ditches face. It indicated that most Little Snake River ditches are water short in late summer, and typically divert for only 6 days in August and 5 days in September. Given this information, monthly efficiencies for April, May, and June were based on average efficiencies for irrigation structures in Colorado's District 54. This approach had been adopted in earlier versions of the Yampa model, before the GRBP information was available. Efficiencies for July, August, and September were set to 0.55, the efficiency used for water short conditions in the GRBP. August and September diversions were then multiplied by 6/31 and 5/30, respectively, to reflect the small number of irrigation days.

With respect to municipal diversions for Baggs and Dixon, the GRBP provided estimated average monthly net depletions by each system, and efficiency on an annual basis. Historical diversions were created for the Yampa model by dividing the monthly depletion amount for each municipality by its respective annual efficiency, then summing those values for the month. The twelve monthly diversions are the same in each year. While these estimates are very approximate, they preserve the annual diversion amount, and are detailed enough given the small magnitude of these diversions.

Historical diversions for all Wyoming structures prior to 1971 and after 1998 were filled using the methods described in Section 4.4.1.1

5.4.3.3.3 Future Use Diversion Structures

All future use structures, including the Endangered Fish requirement (44_WSA), have historical diversions set to zero because they did not divert historically.

5.4.4 Direct Diversion Demand File (*.ddm)

This file contains time series of demand for each structure in the model. Demand is the amount of water the structure "wants" to divert during simulation. In the Yampa model, it is set to the larger of 1) an estimated requirement for the month, and 2) the historical diversion for the month. During times when the diversion was shorted historically, the estimated requirement controls and represents what the structure would divert in order to get a full water supply. During times when the structure diverted a lot of water and operated at lower than average efficiency, the historical diversion controls. The demand represents the amount that would have been diverted given an available supply, as borne out in the historical record. In particular, the historical practice of using irrigation ditches to water livestock in winter, when crop requirement amounts to nothing, can be simulated when demand is approached in this way. Table 5.4 in Section 5.4.1.1 lists average annual demand for each diversion structure.

5.4.4.1 Key Structures

The estimated irrigation requirement for each structure was computed as crop irrigation water requirement for each month divided by the structure's average historical efficiency for the same month. Note that the irrigation water requirement is based on actual climate data beginning in

1950. Prior to that, it is filled using the automatic data filling algorithm described in Section 4.4.2. Monthly efficiency is the average efficiency over the period 1950 through 2005, as calculated by StateCU, but capped at 0.54.

The requirements for municipal and industrial diversions were estimated using recent values or averages of recent records, as recommended by the Hydrology Subcommittee of the Yampa Management Plan effort. Transbasin diversion requirements were estimated as average monthly diversions over the period 1975-1991.

Regardless of use type, the demand was then set to whichever was larger in any given month, the estimated requirement, or the historical diversion.

5.4.4.2 Aggregate Structures

Aggregated irrigation structure demand is computed as for key irrigation structures. The only difference for Colorado structures is that the irrigated acreage, which is the basis of irrigation water requirement, is the sum of irrigated acreage for constituent structures. Similarly diversions are summed across all constituent structures, and average efficiency is based on efficiency of the aggregation in toto. Demand for aggregated M&I structures is the same as it is in the historical diversion file.

5.4.4.3 `Future Use Diversion Structures

Demands of future depletion nodes are zeroed out, as they are not active in the baseline data set.

5.4.5 Direct Diversion Right File (*.ddr)

The direct diversion right file contains water rights information for each diversion structure in the model. **StateDMI** creates the diversion right file, based on the structure list in the diversion station file.

The information in this file is used during simulation to allocate water in the right sequence or priority and to limit the allocation by decreed amount. The file is also an input to **StateDMI** when it is filling historical diversion time series (the *.ddh file). Based on the appropriation dates expressed in the administration number in the rights file, **StateDMI** determines the total amount of the water right during the time of the missing data, and constrains the diversion estimate accordingly. For example, suppose a ditch has two decrees, one for 2.5 cfs with an appropriation date of 1896, and the other for 6 cfs with an appropriation date of 1932. When **StateDMI** estimates diversions prior to 1932, it limits them to a constant rate of 2.5 cfs for the month, regardless of the average from available diversion records. This approach was adopted so that water development over the study period could be simulated.

5.4.5.1 Key Structures

Water rights for explicitly modeled structures were taken from the CDSS database and match the State Engineer's official water rights tabulation. In addition, each right has a "free water right", with an extremely junior administration number of 99996.99999 and a decreed amount of 999.0

cfs. These allow diverters to operate under free river conditions, provided their demand is unsatisfied and water is legally available.

5.4.5.2 Aggregate Structures

Aggregated irrigation structures were assigned all the water rights belonging to their constituent structures. Aggregated M&I water rights were assigned an amount equal to their depletion and assigned an administration number of 1.00000.

5.4.5.3 Special Diversion Rights

5.4.5.3.1 Stillwater Ditch

Water rights for the Stillwater Ditch were divided between the two structures representing the ditch, in accordance with the amount of irrigated acreage under each.

5.4.5.3.2 Wyoming Historical Diversion Structures

Wyoming rights located on tributaries of the Little Snake River, or on the Little Snake River above Slater Creek, were assigned an administration number of 12910.00000. This value places them senior in priority to District 54 direct flow rights in Colorado. In other words, it was assumed that these Wyoming diverters would not be subject to calls from Colorado. Mainstem diverters below Slater Creek were assigned an administration number of 27543.00000, which places them junior to several structures on Slater Creek that were getting called out perennially in the calibration run.

5.4.5.3.3 Future use diversion structures

Future use structures are listed in the direct diversion rights file, but the rights are turned off. This effectively disables the structure with regard to having an impact on the river.

5.5 Irrigation Files

The irrigation files provide parameters used during simulation to compute on-farm consumptive use, and return flow volumes related to a given month's diversion.

5.5.1 StateCU Structure File (*.str)

This file contains the soil moisture capacity of each irrigation structure in inches per inch of soil depth. It is required for StateMod's soil moisture accounting in both baseflow and simulation modes. Soil moisture capacity values were gathered from Natural Resources Conservation Service (NRCS) mapping. The file is assembled by **StateDMI** from hand-built files.

5.5.2 CU Time Series File (*.ipy)

This file is created by **StateDMI**, and contains maximum efficiency and irrigated acreage for each irrigation structure and each year of the study period. In the Yampa model, maximum efficiency has been assumed to be constant over the study period, at 54 percent for all structures. Irrigated acreage is based on 1993 aerial imagery.

5.5.3 Irrigation Water Requirement File (*.iwr)

This file contains the time series of monthly irrigation water requirements for structures whose efficiency varies through the simulation. Irrigation water requirements for Colorado structures are generated by StateCU for the period 1950 through 2005, then filled by **StateDMI**. StateCU was executed using the Blaney-Criddle monthly evapotranspiration option, with elevation adjustment for fields lower than 6,500 feet in elevation, and high altitude crop coefficients for pasture grass above 6,500 feet in elevation. Irrigation water requirement for Wyoming structures was obtained from the GRBP, which produced Normal, Wet, and Dry year designations for 1971 through 1998. It also estimated irrigation water requirement by month in each of those types of years. From this information, a time series of irrigation water requirement was developed for each structure for 1971-1998, and **StateDMI** filled the remaining years.

5.6 Reservoir files

5.6.1 Reservoir Station File (*.res)

This file describes physical properties and some administrative characteristics of each reservoir in the Yampa River model. It is assembled by **StateDMI**, using a considerable amount of information provided in the command file. Ten key reservoirs including High Savery in Wyoming were modeled explicitly. Six aggregated reservoirs in Colorado and four aggregated or minor reservoirs in Wyoming account for evaporation from numerous small storage facilities. In addition, two specific future reservoirs (Pothook and Upper Willow Creek) and one generalized future reservoir have been placed in the model network. They do not actually function in the baseline model. The modeled reservoirs are listed below with their capacity and their number of accounts or pools:

#	ID #	Name	Capacity (af)	# of Owners
1	443902	ELKHEAD RESERVOIR	24778	4
2	583500	ALLEN BASIN RESERVOIR	2250	1
3	583508	FISH CREEK RESERVOIR	4042	1
4	583521	LESTER CK RESERVOIR	5657	1
5	583540	STILLWATER RES 1	6392	8
6	583631	LAKE CATAMOUNT	7422	1
7	583787	STEAMBOAT_LAKE	26364	2
8	584213	STAGECOACH_RESERVOIR	33275	5
9	584240	YAMCOLO RESERVOIR	9096	6
10	44_ARY001	44_ARY001_YampaRbelCraig	23206	1
11	44_ARY002	44_ARY002_Yampa@Deerlodg	9122	1
12	44_ASY001	44_ASY001_YampaRbelCraig	8344	1
13	44_ASY002	44_ASY002_YampaR@Deerlod	4441	1
14	55_ARY003	55_ARY003_LSnakeRnrLily	1494	1
15	55_ASY003	55_ASY003_LSnakeRnrLily	3173	1
16	993000	993000_Wyo_above (Baggs)	860	1
17	993001	993001_Wyo_below (Baggs)	390	1
18	993002	High Savery Reservoir	22433	1
19	993003	993003_Wyo_dikes	1284	1
20	993004	993004_LS_Small_Resvrs	290	1

5.6.1.1 Key Reservoirs

Parameters related to the physical attributes of key reservoirs include inactive storage where applicable, total active storage, area-capacity data, applicable climate stations, and initial contents. For the explicitly modeled Colorado reservoirs, storage and area-capacity information were obtained from either the Division Engineer or the reservoir owners. High Savery Reservoir was configured following a preliminary version of the Little Snake River Supplemental Storage Project model developed by the State of Wyoming. Initial contents for all reservoirs are set to full in the Baseline data set.

Administrative information includes reservoir account ownership, administrative fill date, and evaporation charge specifications. This information was obtained from interviews with the Division engineer, the assistant Division engineer, the local water commissioners, and in most cases the owner/operator of the subject reservoirs. Annual administration is turned off at all reservoirs in the Yampa River model, as inferred from historical records of filling and contents.

5.6.1.2 Aggregate Reservoirs

For Colorado's aggregated reservoirs, amount of storage was based on storage decrees and Task Memo 2:09-12, "Consumptive Use Model Non-Irrigation Consumptive Use and Losses in the Yampa River Basin" (see Appendix B). Surface area for the reservoirs was developed assuming they are straight-sided pits with a depth of 24 feet. According to comments in the reservoir structure file, this number was based on Dam Safety records as summarized in an unpublished U.S. Bureau of Reclamation effort. Initial contents were set to full. Data for Wyoming's aggregated reservoirs was provided with input from the Wyoming State Engineer's Office (see Appendix C).

5.6.1.3 Reservoir Accounts

5.6.1.3.1 Stillwater Reservoir

Stillwater Reservoir No. 1 (WDID 583540) is the most upstream of the major reservoirs in the Yampa River (Bear River) drainage. It is owned by the Bear River Reservoir Co. and provides supplemental irrigation water supplies to several of the major direct flow structures in the upper Bear River. Although its decreed capacity is 6,392, the reservoir company and the water commissioner consider the active storage to be approximately 5,175 acre-feet.

Using reservoir and ditch ownership data provided by the water commissioner, the individually owned storage accounts in Stillwater Reservoir No. 1 were grouped according to the ditch structures that serve the irrigated land owned by those individuals. The active storage in the reservoir is represented in the model with six accounts:

Account	Structure ID	Storage Amount (ac-ft)
Stillwater Ditch		
Colorado Basin	584686	979
Yampa Basin	584685	1,352
Big Mesa Ditch	580539	444
Coal Creek Ditch	580589	435
Lindsey Ditch	580738	394
Mandall Ditch	580763	386
Aggregated Pool[1]		1,185
	TOTAL	5,175

[1] Acton Ditch, Bird Ditch, Buckingham Mandall, Fix Ditch, Hernage & Kolbe, Mill Creek No. 1, Pennsylvania Ditch, Town of Yampa, Others Not in Model

5.6.1.3.2 Yamcolo Reservoir

Yamcolo Reservoir (WDID 584240) is owned and operated by the Upper Yampa Water Conservancy District (UYWCD). UYWCD has allocated the active storage in Yamcolo Reservoir as follows: 1,010 acre-feet for municipal uses; 3,000 acre-feet to the Yamcolo Irrigators Association for irrigation in the upper reaches of the Bear River and 4,000 acre-feet to Tri-State Electric Association or industrial uses. The dead storage of approximately 1,086 acre-feet is reserved for a conservation pool.

Ownership of the 1,010 acre-feet of municipal water comprises small holdings by the Towns of Hayden, Steamboat Springs, Phippsburg, and Yampa, as well as Morrison Creek Water & Sanitation District (WSD) and Mt. Werner WSD. With the exceptions of Steamboat Springs and Mt. Werner WSD, these entities are not modeled explicitly. Accordingly, a single aggregated M&I account has been modeled in Yamcolo Reservoir.

It can be accessed for the other owners' uses if these demands are eventually incorporated into the model.

The Yamcolo Irrigators Association currently consists of about 18 individuals who irrigate land under several of the major ditch structures in the upper Bear River. When the Yampa model was first developed, separate pools were modeled for each owner, based on reservoir account and land ownership data provided by the water commissioner. Diversion records in Hydrobase, however, are not reflective of the account ownership; for example, Lindsey Ditch (580738) was reported to have the second largest account (550 af) but its average delivery was 66 af. Big Mesa Ditch was reported to have a 500-af pool, but showed average deliveries of 795 af, and a maximum of 1807 af in one year. To reflect the flexibility with which the owners can apparently operate, the 3,000-af irrigation pool is now represented by two pools, one for the largest ditch (Stillwater Ditch, 584685 and 584686), and the second for all other irrigators.

Pursuant to a 1992 agreement between UYWCD and Tri-State, Tri-State's 4,000 acre-foot account in Yamcolo Reservoir was effectively moved to Stagecoach Reservoir, and Stagecoach Reservoir agricultural lease water was moved up to Yamcolo Reservoir. Currently the 4,000 acre-feet of so-called "Stagecoach Contract Water", deliverable by exchange through Yamcolo Reservoir, has been contracted primarily to Stillwater Ditch. The pool is represented in the model by two accounts, one for Stillwater Ditch and one for all other users.

Thus the accounts modeled in Yamcolo Reservoir are:

Account	Storage Amount (ac-ft)
Aggregated Irrigators[1] (3,000-af pool)	2,487
Stillwater Ditch (3,000-af pool)	513
Stillwater Stagecoach Contract	3,435
Aggregated Stagecoach Contract Irrigators[2]	565
Aggregated M&I Users	1,010
Conservation Pool	1,086
TOTAL	9,096

[1] Acton , Big Mesa, Bird, Buckingham Mandall, Coal Creek, Egeria ,Fix, Hernage & Kolbe, Lindsey, Mandall, Mill Creek No. 1, and Wooley Ditches; also several more not included explicitly in the model

[2] Acton, Buckingham Mandall, Egeria, Hernage & Kolbe, and Mandall Ditches

5.6.1.3.3 Allen Basin Reservoir

Allen Basin Reservoir (WDID 583500) is a small irrigation reservoir located near the headwaters of Middle Hunt Creek. Although it is smaller than the minimum reservoir capacity (4,000 acre-feet) recommended for inclusion of reservoirs in the Yampa Model, it is being included because it plays a significant role in the irrigation water supply in this water limited area of the Yampa River basin. The reservoir has a decreed capacity of

2,250 acre-feet which is also reported to be its active capacity, there being no dead storage. The reservoir stores water from Middle Hunt Creek as well as water imported from tributaries of South Hunt Creek, via the Allen Basin Supply Ditch (WDID 580506).

Allen Basin Reservoir provides supplemental irrigation supplies to several direct flow ditch structures in the Hunt Creek drainage. Because they are all relatively small, a single aggregated account was modeled in Allen Basin Reservoir.

5.6.1.3.4 Stagecoach Reservoir

Stagecoach Reservoir, the largest storage facility in the Yampa River basin, is owned and operated by UYWCD. The reservoir provides supplemental industrial, agricultural, and municipal water supplies as well as a significantly sized conservation pool for recreational purposes.

The UYWCD originally allocated a total of 15,000 acre-feet of storage water in Stagecoach Reservoir for sale annually as follows: Municipal Users - 2,000 acre-feet; Industrial Users (Tri- State) - 9,000 acre-feet; and Agricultural Users - 4,000 acre-feet. Pursuant to two 1992 Agreements between the UYWCD and Tri-State, the parties agreed to exchange the 4,000 acre-feet of water that Tri-State is entitled to in Yamcolo Reservoir to a Tri-State account in Stagecoach and similarly exchange the 4,000 acre-feet of Agricultural water in Stagecoach upstream to storage in Yamcolo Reservoir. Pursuant to these agreements, Tri-State also reduced its original industrial allocation from 9,000 acre-feet to 7,000 acre-feet. As a result of these Agreements, the storage in Stagecoach Reservoir is now allocated as follows:

Account	Structure ID	Storage Amount (ac-ft)
Industrial Water	440522 and 581583	11,000
Municipal Water	580642	4,000
Recreation Pool	n/a	15,000
Dead Storage	n/a	3,275
TOTAL		33,275

5.6.1.3.5 Lake Catamount

Lake Catamount Reservoir (WDID 583631) is located on the main stem of the Yampa River, between Stagecoach Dam and Steamboat Springs. The reservoir is used primarily for recreation for the planned residential and ski development near the lake. It is modeled simply as having a single conservation pool.

5.6.1.3.6 Fish Creek Reservoir

Fish Creek Reservoir (WDID 583508) is owned by the city of Steamboat Springs and used as reserve raw water storage for the city and for the Mt. Werner WSD. It was expanded from a capacity of 1,842 acre-feet to 4,042 acre-feet in 1996. It is modeled simply as having one 4,042-af pool serving the combined demand of Steamboat Springs and Mt. Werner WSD.

5.6.1.3.7 Steamboat Lake

Steamboat Lake (WDID 583787) is located on Willow Creek, a tributary of the Elk River. Owned and operated by the Colorado Division of Parks and Outdoor Recreation (CPOR), it is used for recreational and industrial purposes. Construction costs for the dam and reservoir were partially paid for by the Salt River Generating Co. and Colorado-Ute Electric Association (the partners in the operation of the Hayden Station power plant) in return for a perpetual right to withdraw 5,000 acre-feet of water per year from the reservoir. This water is the supplemental water supply for the operation of the Hayden Station.

Historically, CPOR has been allowed to store water above the normal spillway elevation, encroaching upon the flood surcharge capacity of the reservoir. This arrangement has been made permanent with the installation of spillway gates and acquisition of an additional water right to store in the additional capacity (approximately 3,300 acre-feet). Of this enlargement, CPOR has contracted to lease up to 125 acre-feet per year to the Cyprus Empire Corp. for use in an augmentation plan. The remainder of CPOR's interest in the Steamboat Lake water rights are for recreational and conservation pool purposes at the reservoir itself. Accordingly, Steamboat Lake is modeled as having two accounts, the Hayden Station's 5,000 acre-feet, and CPOR's 21,364 acre-feet. The latter includes the 125 acre-feet leased by Cyprus Empire, whose augmentation is not explicitly represented in the Yampa Model.

Account	Structure ID	Storage Amount (ac-ft)
Hayden Station	570512	5,000
Conservation Pool		21,364
TOTAL		26,364

5.6.1.3.8 Lester Creek Reservoir (Pearl Lake)

Lester Creek Reservoir (WDID 583521) is owned and operated by CDOW and used exclusively for recreation and fishery purposes. The reservoir is included in the Yampa Model primarily to account for the consumptive evaporation losses from the reservoir. It has a single conservation pool in the Yampa River model.

5.6.1.3.9 Elkhead Reservoir

Elkhead Creek Reservoir (WDID 443902) is located on Elkhead Creek, a tributary of the Yampa River just upstream of the city of Craig. The reservoir was originally constructed by the Colorado Division of Wildlife (CDOW) and the Yampa Project Participants (the operating consortium for the Craig Station power plant) for recreational and industrial purposes. The Yampa Participants funded a portion of the construction in return for full use of the active storage capacity in the reservoir above elevation 6340.5, while CDOW retained use of the storage capacity below this elevation.

In 1990, the city of Craig acquired all of the CDOW's interests in the reservoir, subject to a contractual commitment to not encroach upon the dead storage, which is reserved as a conservation pool for the benefit of the CDOW. In 1991, the reservoir was emptied to the approximate dead storage level for maintenance, and re-surveyed. From this new survey data, the city has estimated that the active capacity above the outlet works invert is about 10,422 acre-feet. Of this storage, the Yampa Participants' entitlement is estimated to be about 8,754 acre-feet and the city's entitlement about 1,668 acre-feet. In 2006, the Colorado River Water Conservation District enlarged Elkhead Reservoir to a total volume of 24,778 acre-feet. During construction, the reservoir was again surveyed, this time with the result that the volume below elevation 6,340.5 feet was 4,413 acre-feet; the pre-enlargement capacity above 6,340.5 feet was 8,408 acre-feet, and the enlargement volume was 11,957 acre-feet. Of the enlargement pool, 5,000 acre-feet was deeded to the Colorado Water Conservation Board for the purpose of maintaining base flow through critical habitat reach in the lower Yampa, on behalf of the Upper Colorado River Basin Endangered Fish Recovery Program. Accordingly, the reservoir is modeled with four accounts:

Account	Structure ID	Storage Amount (ac-ft)
Yampa Participants	580522	8,408
City of Craig	580581	4,413
CWCB	442500	5,000
CRWCD	n/a	6,957
	TOTAL	24,778

5.6.1.3.10 Wyoming Reservoirs (and Pothook site)

The model includes eight reservoir structures in Wyoming. The largest, High Savery Reservoir (993002), began operating in 2006. It is modeled as having 22,433 acre-feet of active capacity, represented with one account. There are four structures representing aggregated small storage in Wyoming. The first represents irrigation storage supply above Baggs (993000), the second represents irrigation storage supply below Baggs (993001), the third represents the diked wetlands on Muddy Creek.(993003), and the fourth represents stockponds (993004). All of the aggregated reservoirs are less than 1500 acre-feet in size. Three nodes represent future reservoirs, one at the Pothook site (544208 , it is actually situated within Colorado), one at the Upper Willow Creek site (993007), and a third representing aggregated future storage of 16,000 acre-feet (993005). The State of Wyoming provided physical information for the small Wyoming reservoirs in a technical memorandum titled “Green River Basin Plan Wyoming Depletions in the Little Snake River Basin”, dated August, 2000 (see Appendix C). Information for High Savery Reservoir was taken from a preliminary version of a StateMod model that Wyoming developed under the Little Snake River Supplemental Storage study, which was pending as of 2009. Initial contents for High Savery and the aggregated reservoirs are set to capacity; initial contents for the future sites are zero. The

Wyoming reservoirs use the same monthly net evaporation rates as the Colorado reservoirs.

6.5.2 Net Evaporation File (*.eva)

The evaporation file contains monthly average evaporation data (12 values that are applied in every year). The annual net reservoir evaporation was estimated by subtracting the weighted average effective monthly precipitation from the estimated gross monthly free water surface evaporation. Annual estimates of gross free water surface evaporation were taken from the National Oceanic and Atmospheric Administration (NOAA) Technical Report NWS 33. The annual estimates of evaporation were distributed to monthly values based on elevation through the distributions listed in Table 5.6. These monthly distributions are used by the State Engineer's Office.

Table 5.6
Monthly Distribution of Evaporation as a Function of Elevation (percent)

Month	Greater than 6,500 ft	Less than 6,500 ft
Jan	3.0	1.0
Feb	3.5	3.0
Mar	5.5	6.0
Apr	9.0	9.0
May	12.0	12.5
Jun	14.5	15.5
Jul	15.0	16.0
Aug	13.5	13.0
Sep	10.0	11.0
Oct	7.0	7.5
Nov	4.0	4.0
Dec	3.0	1.5

Precipitation stations at Steamboat Springs and Yampa, Colorado, were used in the calculation of annual net reservoir evaporation for the Yampa basin. The resulting net monthly free water surface evaporation estimates for the Yampa River basin are shown below:

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
.13	-.01	-.11	-.12	-.03	.06	.15	.28	.40	.39	.29	.25

5.6.3 EOM Content File (*.eom)

The end-of-month content file contains historical end-of-month storage contents for all reservoirs in the reservoir station file. The historical EOM reservoir contents in this file are used by StateMod when estimating baseflow to reverse the effects of reservoir storage and evaporation on gaged streamflows, and to produce comparison output useful during calibration. The file is created by **TsTool**, which reads data from Hydrobase and can fill it under a variety of user-specified algorithms.

5.6.3.1 Key Reservoirs

Data for the larger reservoirs (Yamcolo, Stagecoach, and Elkhead Reservoirs, and Steamboat Lake) was provided by Division 6 or generated by converting sporadic observations from Hydrobase to month-end data. The user-specified tolerance for defining the end of the month was set to 16 days. Generally, other reservoirs' contents were from monthly tables in the database, and filled by **TsTool**, given a pattern file containing the hydrologic condition for each month of the study period. Missing end-of-month contents were filled with the average of available content values for months with the same hydrologic condition. Table 5.7 presents the on-line date for each reservoir. Historical contents in the *.eom file for the respective reservoirs are zero prior to these dates

Table 5.7
Reservoir On-line Dates

Reservoir	On-Line Date
Allen Basin	1909
Stillwater	1939
Fish Creek	1956
Steamboat Lake	1965
Lester Creek	1975
Elkhead	1975
Lake Catamount	1978
Yamcolo	1980
Stagecoach	1988
High Savery	2003

5.6.3.2 Aggregate Reservoirs

Aggregated reservoirs, in both Colorado and Wyoming, were assigned initial contents equal to their capacity, because there is no actual data. Aggregated reservoirs were modeled as though in operation throughout the study period.

5.6.4 Reservoir Target File (*.tar)

The reservoir target file contains minimum and maximum target storage limits for all reservoirs in the reservoir station file. The reservoir may not store more than the maximum target, or release to the extent that storage falls below the minimum target. In the Baseline data set, the minimum targets are set to zero and maximum targets are set to capacity for all reservoirs, except for Lake Catamount. These targets allow maximum control of reservoir levels by storage rights and releases to meet demands.

Lake Catamount uses maximum targets that help replicate seasonal operations apparent in the historical record, since no demands on the reservoir are currently included in the model. To do this, the October target is set to 5,200 af, about 2,200 af below the maximum capacity. StateMod's "forecast" target feature is used to control filling from November through March. During these months, the target is computed dynamically each month, based on the simulated end-of-month contents, the March target, and the number of months remaining in which to achieve the March target. The calculation assumes that the reservoir will be filled by the same amount in each month remaining in the forecast period.

Fish Creek Reservoir uses its current enlarged capacity of 4,042 af as the maximum target throughout the modeling period.

5.6.5 Reservoir Right File (*.rer)

The reservoir right file contains the water rights associated with each reservoir in the reservoir station file. Specifically, the parameters for each storage right include the reservoir, administration number, decreed amount, the account(s) to which exercise of the right accrues, and whether the right is used as a first or second fill.

5.6.5.1 Key Reservoirs

In general, water rights for explicitly modeled reservoirs were taken from the CDSS database and correspond to the State Engineer's official water rights tabulation. The water right for High Savery Reservoir was adopted from the Little Snake model developed for the Little Snake River Supplemental Storage project.

5.6.5.2 Aggregate Reservoirs

Aggregated reservoirs and stock ponds were assigned a decreed amount equal to their capacity, and an administration number of 1.00000.

5.6.5.3 Special Reservoir Rights

5.6.5.3.1 Yamcolo Reservoir

Yamcolo Reservoir has four storage rights totaling 11,471 acre-feet. The most senior right, for 6,532 acre-feet was broken into three artificial rights in order to model the following practice. Among the three general accounts in Yamcolo Reservoir (municipal, irrigation, and the Stagecoach Contract exchange), the municipal account is filled first, then the Yamcolo Irrigators Association account, and last, the Stagecoach Contract account. Therefore, three separate rights were modeled. The first stores up to 1,010 ac-ft in the municipal account under the right's actual administration number, 41329.00000. The second stores to the aggregated Yamcolo Irrigators Association account and the Stillwater Ditch account within the Yamcolo Irrigators 3,000-af pool, at administration number 41329.00001. The balance of the right, 2,521 ac-ft, is then stored to the pool representing Stillwater Ditch's use of Stagecoach contract water, under administration number 41329.00002. Yamcolo's more junior rights can fill the aggregate Stagecoach contract pool in the reservoir, as well as any unfilled portion of any of the pools. StateMod does not strictly model the accounting nuances of all of Yamcolo's decrees, but calibration shows that, in general, reservoir storage reflects historical operation and is adequate for basin planning.

5.6.3.2 Stagecoach Reservoir

Stagecoach Reservoir is modeled as having nine storage rights. The most senior five rights are small senior transferred rights that were associated with the ditches inundated by the reservoir. These rights, which are typically satisfied in the first several days of the runoff season, are assigned in the model to the Tri-State pool.

The next two rights in terms of priority are a disaggregation of Stagecoach's storage right for 11,614 acre-feet, which was part of the former Wessels Project. The storage right has the same priority as the Wessels Canal direct flow right, which is owned in part by Tri-State, for diversion at the Craig Station. Pursuant to a 1992 agreement between UYWCD and Tri-State, the UYWCD's storage decree is subordinated to the priority of Tri-State's Wessels Canal flow right, to the extent that there is insufficient flow for both. The right is divided into two in the model to simulate the practice of filling Tri-State's original allocation of 7,000 acre-feet first. The remaining 4,614 acre-feet is used to fill the remainder of the Tri-State pool and the aggregated municipal account. These artificial rights have administration numbers of 40815.00000 and 40815.00001, which not only maintains the correct priority with respect to one another, but also partially subordinates the storage right to the Wessels Canal right.

The right for 20,854 acre feet is part of a conditional decree for 40,720 acre-feet, transferred from the former Pleasant Valley Reservoir site where Lake Catamount is now located. In 1994, UYWCD made 20,854 acre-feet of this conditional water right absolute at Stagecoach Reservoir. It is used to fill all the reservoir accounts.

The most junior right for 6,670 acre-feet is a refill right that is used to fill all accounts.

StateMod does not currently model several rights senior to the Wessels right, which were decreed originally to the Four Counties Project. UYWCD successfully sought to make Stagecoach an alternate point for the rights, which are specified as flow rates rather than storage volumes. The Four Counties rights that have been made absolute now total 151 cfs. UYWCD must inform the Division Office each year if they intend to account for use of the rights in the coming accounting year, and storage is subject to water availability at the original point of diversion. Because the rights are used irregularly, and because there is virtually never a call on the river at Stagecoach Reservoir, this feature of Stagecoach Reservoir was not included in the model.

5.6.3.3 Elkhead Creek Reservoir

Seven storage rights are used to model Elkhead Reservoir storage. Original owners of the reservoir, CDOW and the power consortium known as the Yampa Participants, each had rights relating to their own pools. A right for 5,389 acre-feet was deeded by CDOW to the City of Craig, and is used to fill the City's account. The Yampa Participants right for 8,310 acre-feet is used to fill the Participants' pool. Two rights with administration number 41126.00000, which is senior to the original Elkhead Reservoir rights, represent the portions of a conditional right for California Park Reservoir that were transferred to the two owners. The City of Craig's right for 4,945 acre-feet can be used as a first fill right. The Yampa Participants right for 8,754 acre-feet may only be used to refill their account. The last three rights are a disaggregation of the enlargement right of 13,000 acre-feet that was sought by the Colorado River Water Conservation District. Of this right, 5,000 acre-feet is assigned to the CWCB pool for endangered fish pool, 7,000 acre-feet is assigned to the River District's unallocated pool, and 1,000 acre-feet can be used to refill the enlargement, as allowed by the decree.

5.7 Instream Flow Files

5.7.1 Instream Station File (*.ifs)

Twenty-four instream flow stations are defined in this file, which is created by **StateDMI**. The file specifies an instream flow station and downstream terminus node (if applicable) for each reach, through which instream flow rights can exert a demand in priority. Table 5.8 lists each instream flow station included in the Yampa Model along with their location and average annual demand. With two exceptions, these rights represent decrees acquired by CWCB.

Instream flow structure 44_EDF2 is the modeled instream flow requirement for the endangered species critical habitat reach, per the Endangered Fish Recovery Program. The second non-CWCB instream flow right is the Steamboat Springs Boating Park Recreational In-channel Diversion.

5.7.2 Instream Demand File (*.ifa)

Instream flow demands were developed from decreed amounts and comments in the state engineer's water rights tabulation. The same twelve monthly instream flow demands are used for each year of the simulation. Demand for 44_EDF2, the critical habitat reach minimum flow is set to 150 cfs for August, 300 cfs for September, and 150 cfs for October. The minimum flow rate is based on Recovery Program requests for flow maintenance of 300 cfs from late August through September, during both 2008 and 2009.

5.7.3 Instream Right File (*.ifr)

Water rights for each instream flow reach modeled in the Yampa River basin are contained in the instream flow right file. These data were obtained from the CWCB instream flow database.

Table 5.8
Instream Flow Summary

ID	Name	Location	Demand (af/yr)
441448	Williams_Fork_River_MSF	Williams Fork, confluence S. Fork and East Fork Williams Fork to Morapos Creek	14,965
441452	East_Fk_Williams_Fk_MSF	East Fork Williams Fork, confluence West Fork to Poose Creek	10,259
441456	South Fk Williams Fk	S. Fork Williams Fork, confluence	4,256

ID	Name	Location	Demand (af/yr)
	MSF	Pagoda Creek to confluence Beaver Creek	
44_EDF2	Fish Habitat Min Flow	Yampa River near Maybell	36,199
542076	Slater Creek MSF	Headwaters to Forest Service boundary	2,172
571009	Trout Creek MSF-L	Trout Creek, head water node to Yampa River	3,620
581355	Elk River MSF-L	Elk River, confluence with Rock Creek to Yampa River	47,059
581461	Willow Ck MSF-M2	Willow Creek, confluence with Beaver Creek (below Steamboat Lake) to Elk River	3,620
582164	Yampa River MSF	Yampa River, Morrison Creek to Lake Catamount	41,180
582202	Bear River MSF-L	Bear River, Yamcolo Reservoir to confluence with Phillips Creek	8,688
582206	Big Creek MSF	Confluence Middle Fork Big Creek to Elk River	10,860
582214	Coal Creek MSF	Coal Creek, tributary to Bear River	3,620
582216	Dome Creek MSF	Dome Creek, headwaters to Bear River	1,448
582219	Elk River MSF-U	Elk River, confluence Middle Fork Elk River to Rock Creek	47,059
582245	Green Creek MSF	Green Creek, headwaters to Yampa River	3,620
582287	North Fk Fish Creek MSF-L	N. Fork Fish Creek, confluence with Middle Fork Fish Creek to Fish Creek	3,620
582290	Oak Creek MSF	Oak Creek, headwaters to Forest Service boundary	1,448
582306	Service Creek MSF	Service Creek, confluence North Fork Service Creek to Yampa River	4,344
582311	Soda Creek MSF	Soda Creek, headwaters to Routt Forest boundary	3,620
582332	Willow Ck MSF-L	Willow Creek, confluence Beaver Creek to Elk River	5,068
582404	Bear River MSF-M	Bear River, Stillwater Reservoir to Yamcolo Reservoir	5,744
582409	Phillips Cr MSF	Phillips Creek, confluence Chimney Creek to Bear River	4,344
582519	Hunt Creek MSF	Hunt Creek, confluence S. Fork Hunt Creek to Bear River	3,620
582591	Steamboat Springs Boating Park		68,553

5.8 Operating Rights File (*.opr)

The operating rights file specifies all operations that are more complicated than a direct diversion or storage in an onstream reservoir. Typically, these are reservoir operations involving two or more structures, such as a release from a reservoir to a diversion structure, a release from one reservoir to a second reservoir, or a diversion to an offstream reservoir. The file is created by hand, and the user is required to assign each operating right an administration number consistent with the structures' other rights and operations.

In the Yampa River model, six different types of operating rights are used:

- Type 1 – a release from storage to the stream to satisfy an instream flow demand.
- Type 2 - a release from storage to the stream, for shepherded delivery to a downstream diversion. Typically, the reservoir supply is supplemental, and its release is given an administration number junior to direct flow rights at the destination structure. A release is made only if demand at the diversion structure is not satisfied after direct flow rights have diverted.
- Type 3 – a release from storage to a carrier (a ditch or canal as opposed to the river), for delivery to a diversion station. Typically, the reservoir supply is supplemental, and its release is given an administration number junior to direct flow rights at the destination structure. A release is made only if demand at the diversion structure is not satisfied after direct flow rights have diverted.
- Type 4 - a release from storage, in exchange for a direct diversion elsewhere in the system. The release can occur only to the extent that legally available water occurs in the exchange reach. Typically, the storage water is supplemental supply, and is given an administration number junior to direct flow rights at the diverting structure.
- Type 9 – a release from storage to the river to meet a reservoir target. This operation is generally used in calibration and is turned off in the baseline data set.
- Type 11 – a direct flow diversion to another diversion or reservoir through an intervening carrier. It uses the administration number and decreed amount of the direct flow right associated with the carrier, regardless of the administration number assigned to the operating right itself. If the destination is a reservoir (as in the only example of this right's application in the Yampa model, to fill Allen Basin Reservoir), the demand is the destination reservoir's capacity.

This presentation of operating rights for the Yampa model is organized according to the reservoirs involved:

Section	Description
5.8.1	Stillwater Reservoir
5.8.2	Yamcolo Reservoir
5.8.3	Allen Basin Reservoir
5.8.4	Stagecoach Reservoir
5.8.5	Lake Catamount
5.8.6	Fish Creek Reservoir
5.8.7	Steamboat Lake
5.8.8	Lester Creek Reservoir
5.8.9	Elkhead Creek Reservoir
5.8.10	High Savery Reservoir

Where to find more information

- StateMod documentation describes all the different types of operating rights that can be specified in this file, and describes format of the file.
- The section "Yampa River Projects and Special Operations" in the document "Yampa Basin Information" describes each reservoir's typical operations.

5.8.1 Stillwater Reservoir

Stillwater Reservoir No. 1 (WDID 583540) is owned by the Bear River Reservoir Company and provides supplemental irrigation water supplies to several of the major direct flow structures in the upper Bear River. Based on reservoir and ditch ownership data provided by the Division Engineer, eight storage accounts were modeled in Stillwater Reservoir No. 1, as shown below. Each account represents the combined ownership of individuals served by a specific ditch, except for accounts 7 and 8. Account 7 represents the combined small ownership by Acton, Bird, Buckingham Mandall, Fix, Hernage & Kolbe, Mill Creek No. 1, and Pennsylvania Ditches; account 8 was modeled to reduce the total decreed storage (6,392 acre-feet) so that it matches the active storage (5,175 acre-feet), and makes no releases in the model.

Account	Owner	Capacity (acre-feet)
1	BIG MESA DITCH	444
2	COAL CREEK DITCH	435
3	LINDSEY DITCH	394
4	MANDALL DITCH	386
5	STILLWATER D.-CO	979
6	STILLWATER D.-YAMPA	1,352
7	AGGREGATED POOL	1,185
8	UNALLOCATED POOL	1,217

Fourteen operating rights are used to specify Stillwater Reservoir operations:

Right #	Destination	Resvr Account	Admin #	Right Type	Description
1	Acton Ditch	7	33782.31055	2	Release to direct diversion
2	Big Mesa Ditch	1	35924.00002	2	Release to direct diversion
3	Bird Ditch	7	33782.31055	2	Release to direct diversion
4	Buckingham-Mandall Ditch	7	33782.31055	2	Release to direct diversion
5	Coal Creek Ditch (ADY_001)	2	35320.34866	2	Release to direct diversion
6	Fix Ditch	7	33782.31055	2	Release to direct diversion
7	Hern-Kolbe Ditch	7	51134.44105	2	Release to direct diversion
8	Lindsey Ditch	3	33782.31055	2	Release to direct diversion
9	Mandall Ditch	4	33782.31055	2	Release to direct diversion
10	Mill Creek No. 1 Ditch	7	51134.44105	2	Release to direct diversion
11	Pennsylvania Ditch	7	33782.31055	2	Release to direct diversion
12	Stillwater Ditch (Yampa)	6	33782.31055	2	Release to direct diversion
13	Stillwater Ditch (Colorado)	5	33782.31055	2	Release to direct diversion
14	Opr Stillwater to Target	1 through 8	99999.99999	9	Res to River by Target

Operating right 1 releases water from the aggregated account (7) to the Acton Ditch (580500). The administration number for this operating right is junior to both the Acton Ditch's direct flow rights and the storage right at Stillwater Reservoir. The Acton Ditch is modeled as drawing out of storage in Stillwater Reservoir before drawing from its accounts in Yamcolo Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the aggregated account, and the unsatisfied demand at the Acton Ditch.

Operating right 2 releases water from account 1 to the Big Mesa Ditch (580539). The administration number for this operating right is junior to both the direct flow right at the direct diversion and the storage right at Stillwater Reservoir. Big Mesa Ditch is modeled as drawing out of storage in Stillwater Reservoir before drawing from its account in Yamcolo Reservoir.The amount of water released to the direct diversion is restricted by the amount currently available in the account, and unsatisfied demand at Big Mesa Ditch.

Operating right 3 releases water from the aggregated account to the Bird Ditch (580541). The administration number for this operating right is junior to both the direct flow right at the direct diversion and the storage right at Stillwater Reservoir. Bird Ditch is modeled as drawing out of storage in Stillwater Reservoir before drawing from its account in Yamcolo Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at Bird Ditch.

Operating right 4 releases water from the aggregated account to the Buckingham Mandall Ditch (580564). The administration number for this operating right is junior to both the direct flow right at the direct diversion and the storage right at Stillwater Reservoir. Buckingham Mandall Ditch is modeled as drawing out of storage in Stillwater Reservoir before drawing from its accounts in Yamcolo Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and unsatisfied demand at the Buckingham Mandall Ditch.

Operating right 5 releases water from account 2 to enable diversion at aggregate 58_ADY001, which includes the Coal Creek Ditch. The administration number for this operating right is junior to both the direct flow right at the direct diversion and the storage right at Stillwater Reservoir. It is senior, however, to releases from Yamcolo Reservoir for the same purpose. The model probably overstates yield of this operating right, as it cannot constrain the release to satisfy only Coal Creek Ditch's demand. Instead, it will deliver water to the unmet demand at 58_ADY001, which includes many other ditches' demands. Furthermore, in the real world, the delivery must be made by exchange, which would limit exercise of the operating right from time to time. But the aggregate node is located downstream from the reservoir in the model, meaning there are never exchange limitations on the release.

Operating right 6 releases water from the aggregated account to the Fix Ditch (580643). The administration number for this operating right is junior to both the direct flow right at the direct diversion and the storage right at Stillwater Reservoir. The Fix Ditch is modeled as drawing out of storage in Stillwater Reservoir before drawing from its account in Yamcolo Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and unsatisfied demand at the Fix Ditch.

Operating right 7 releases water from the aggregated account to the Hernage and Kolbe Ditch (580684). The administration number for this operating right is junior to both the direct flow right at the direct diversion and the storage right at Stillwater Reservoir. The Hernage and Kolbe Ditch are modeled as drawing out of storage in Stillwater Reservoir before drawing from its accounts in Yamcolo Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and unsatisfied demand at the Hernage and Kolbe Ditch.

Operating right 8 releases water from account 3 to the Lindsey Ditch (580738). The administration number for this operating right is junior to both the direct flow right at the direct diversion and the storage right at Stillwater Reservoir. Lindsey Ditch is modeled as drawing out of storage in Stillwater Reservoir before drawing from its account in Yamcolo Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and unsatisfied demand at the Lindsey Ditch.

Operating right 9 releases water from account 4 to the Mandall Ditch (580763). The administration number for this operating right is junior to both the direct flow right at the direct diversion and the storage right at Stillwater Reservoir. Mandall Ditch is modeled as drawing out of storage in Stillwater Reservoir before drawing from its accounts in Yamcolo Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and unsatisfied demand at the Mandall Ditch.

Operating right 10 releases water from the aggregated account to the Mill Ditch No. 1 (580777). The administration number for this operating right is junior to both the direct flow right at the direct diversion and the storage right at Stillwater Reservoir. Mill Ditch No. 1 is modeled as drawing out of storage in Stillwater Reservoir before drawing from its account in Yamcolo Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and unsatisfied demand at Mill Ditch No. 1.

Operating right 11 releases water from the aggregated account to the Pennsylvania Ditch (580821). The administration number for this operating right is junior to both the direct flow right at the direct diversion and the storage right at Stillwater Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and unsatisfied demand at the Pennsylvania Ditch.

Operating right 12 releases water from account 6 to the Stillwater Ditch irrigating in Division 6 (584685). The administration number for this operating right is junior to both the direct flow right at the direct diversion and the storage right at Stillwater Reservoir. Stillwater Ditch is modeled as drawing out of storage in Stillwater Reservoir before drawing from its accounts in Yamcolo Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and unsatisfied demand at the destination structure.

Operating right 13 releases water from account 5 to the Stillwater Ditch irrigating in Division 5 (584686). The administration number for this operating right is junior to both the direct flow right at the direct diversion and the storage right at Stillwater Reservoir. Stillwater Ditch is modeled as drawing out of storage in Stillwater Reservoir before drawing from its accounts in Yamcolo Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account.

Operating right 14 is turned OFF in the baseline data set. It was used in the first calibration run, to release water to meet the historical end-of-month content if modeled contents are above historical contents after all demand-based releases occur. The release is made from all reservoir accounts in proportion to the current contents of each account. The junior administration number ensures this is the last operating right to fire.

5.8.2 Yamcolo Reservoir

Yamcolo Reservoir (WDID 584240) provides supplemental irrigation water to the critically water short reaches of the upper Yampa River (Bear River). It also has a relatively small pool allocated to municipal use. Yamcolo is operated with twelve accounts, which are listed below and described more detail in Section 5.6.1.3.2.

Account	Owner	Capacity (acre-feet)
1	Aggregated Irrigators (3,000-af pool)	2,487
2	Stillwater Ditch (3,000-af pool)	513
3	Stillwater Stagecoach Contract	3,435
4	Aggregated Stagecoach Contract Irrigators	565
5	Aggregated M&I Users	1,010
6	Conservation Pool	1,086

Twenty-four operating rights are used to simulate Yamcolo operations. Several rights are required to serve the various owners in the aggregated pools:

Right #	Destination	Reservoir Account	Admin #	Right Type	Description
1	Acton Ditch	1	51134.47907	2	Release to direct diversion
2	Big Mesa Ditch	1	51134.47906	2	Release to direct diversion
3	Bird Ditch	1	51134.47906	2	Release to direct diversion
4	Buckingham-Mandall Ditch	1	51134.47907	2	Release to direct diversion
5	Coal Creek Ditch (58_ADY001)	1	51134.47906	2	Release to direct diversion
6	Fix Ditch	1	51134.47906	2	Release to direct diversion
7	Hern-Kolbe Ditch	1	51134.47907	2	Release to direct diversion
8	Lindsey Ditch	1	51134.47906	2	Release to direct diversion
9	Mandall Ditch	1	51134.47907	2	Release to direct diversion
10	Egeria Ditch	1	51134.47907	2	Release to direct diversion
11	Wooley Ditch	1	51134.47906	2	Release to direct diversion
12	Mill Creek No. 1 Ditch	1	51134.47906	2	Release to direct diversion
13	Stillwater Ditch (Yampa)	2	51134.47906	2	Release to direct diversion
14	Stillwater Ditch (Colorado)	2	51134.47906	2	Release to direct diversion
15	Pennsylvania Ditch	1	51134.47906	2	Release to direct diversion
16	Acton	4	51134.47907	2	Release to direct diversion
17	Buckingham-Mandall Ditch	4	51134.47906	2	Release to direct diversion
18	Egeria	4	51134.47907	2	Release to direct diversion
19	Hern-Kolbe Ditch	4	51134.47907	2	Release to direct diversion
20	Mandall Ditch	4	51134.47907	2	Release to direct diversion
21	Stillwater Ditch (Yampa)	3	51134.47909	2	Release to direct diversion
22	Stillwater Ditch (Colorado)	3	51134.47909	2	Release to direct diversion
23	Fish Creek Municipal Intake	5	51134.47909	4	Release to direct diversion
24	Opr Yamcolo to Target	1 through 12	99999.99999	9	Res to River by Target

Operating right 1 releases water from the aggregated irrigators' account to the Acton Ditch (580500). The administration number is junior to the Acton Ditch's direct flow rights, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Acton Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Acton Ditch.

Operating right 2 releases water from account 1 to the Big Mesa Ditch (580539). The administration number is junior to the Big Mesa Ditch's direct flow rights, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Big Mesa Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Big Mesa Ditch.

Operating right 3 releases water from account 1 to the Bird Ditch (580541). The administration number is junior to the Bird Ditch's direct flow rights, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Bird Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Bird Ditch.

Operating right 4 releases water from the aggregated irrigators' account to the Buckingham-Mandall Ditch (580564). The administration number is junior to the Buckingham-Mandall Ditch's direct flow rights, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Buckingham-Mandall Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Buckingham-Mandall Ditch.

Operating right 5 releases water from account 1 to enable diversion at aggregated 58_ADY001, which includes the Coal Creek Ditch. The administration number for this operating right is junior to the direct flow right at the Coal Creek Ditch, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir for the Coal Creek Ditch. The model probably overstates yield of this operating right, as it cannot constrain the release to satisfy only Coal Creek Ditch's demand. Instead, it will deliver water to the unmet demand at 58_ADY001, which includes many other ditches' demands. Furthermore, in the real world, the delivery must be made by exchange, which would limit exercise of the operating right from time to time. But the aggregate node is located downstream from the reservoir in the model, meaning there are never exchange limitations on the release.

Operating right 6 releases water from the aggregated irrigators' account to the Fix Ditch (580643). The administration number is junior to the Fix Ditch's direct flow rights, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Fix Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Fix Ditch.

Operating right 7 releases water from the aggregated irrigators' account to the Hernage and Kolbe Ditch (580684). The administration number is junior to the Hernage and Kolbe Ditch's direct flow rights, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Hernage and Kolbe Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Hernage and Kolbe Ditch.

Operating right 8 releases water from account 1 to the Lindsey Ditch (580738). The administration number is junior to the Lindsey Ditch's direct flow rights, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Lindsey Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Lindsey Ditch.

Operating right 9 releases water from the aggregated irrigators' account to the Mandall Ditch (580643). The administration number is junior to the Mandall Ditch's direct flow rights, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Mandall Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Mandall Ditch.

Operating right 10 releases water from the aggregated irrigators' account to the Egeria Ditch (580622). The administration number is junior to the Egeria Ditch's direct flow rights and, the storage rights at Yamcolo Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Egeria Ditch.

Operating right 11 releases water from the aggregated irrigators' account to the Wooley Ditch (580945). The administration number is junior to the Wooley Ditch's direct flow rights and the storage rights at Yamcolo Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Wooley Ditch.

Operating right 12 releases water from the aggregated irrigators' account to the Mill Creek No. 1 Ditch (580777). The administration number is junior to the Mill Creek No. 1 Ditch's direct flow rights, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Mill Creek No. 1 Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Mill Creek No. 1 Ditch.

Operating right 13 releases water from account 2 to the Stillwater Ditch (584685) irrigating in Division 6. The administration number for this operating right is junior to the direct flow right at the diversion station, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Stillwater Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and unsatisfied demand at the Stillwater Ditch (Yampa portion).

Operating right 14 releases water from account 2 to the Stillwater Ditch (584686) irrigating in Division 5. The administration number for this operating right is junior to the direct flow right at the diversion station, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Stillwater Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and unsatisfied demand at the Stillwater Ditch (Colorado portion).

Operating right 15 releases water from the aggregated irrigators' account to the Pennsylvania Ditch (580821). The administration number is junior to the Pennsylvania Ditch's direct flow rights and the storage rights at Yamcolo Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Pennsylvania Ditch.

Operating right 16 releases water from the aggregated Stagecoach contract account to the Acton Ditch (580500). The administration number is junior to the Acton Ditch's direct flow rights, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Acton Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Acton Ditch.

Operating right 17 releases water from the aggregated Stagecoach contract account to the Buckingham-Mandall Ditch (580564). The administration number is junior to the Buckingham-Mandall Ditch's direct flow rights, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Buckingham-Mandall Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Buckingham-Mandall Ditch.

Operating right 18 releases water from the aggregated Stagecoach contract account to the Egeria Ditch (580622). The administration number is junior to the Egeria Ditch's direct flow rights and, the storage rights at Yamcolo Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Egeria Ditch.

Operating right 19 releases water from the aggregated Stagecoach contract account to the Hernage and Kolbe Ditch (580684). The administration number is junior to the Hernage and Kolbe Ditch's direct flow rights, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Hernage and Kolbe Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Hernage and Kolbe Ditch.

Operating right 20 releases water from the aggregated Stagecoach contract account to the Mandall Ditch (580643). The administration number is junior to the Mandall Ditch's direct flow rights, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Mandall Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and the unsatisfied demand at the Mandall Ditch.

Operating right 21 releases water from account 3 (Stillwater Ditch (Yampa basin)'s portion of the Stagecoach contract account) to the Stillwater Ditch (584685) irrigating in Division 6. The administration number for this operating right is junior to the direct flow right at the diversion station, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Stillwater Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and unsatisfied demand at the Stillwater Ditch (Yampa portion).

Operating right 22 releases water from account 3 (Stillwater Ditch (Colorado basin)'s portion of the Stagecoach contract account) to the Stillwater Ditch (584686) irrigating in Division 5. The administration number for this operating right is junior to the direct flow right at the diversion station, the storage rights at Yamcolo Reservoir, and reservoir releases from Stillwater Reservoir to the Stillwater Ditch. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and unsatisfied demand at the Stillwater Ditch (Colorado portion).

Operating right 23 releases water from account 5 to allow diversions at the Fish Creek Municipal intake (580642) by exchange. The administration number for this operating right is junior to both the direct flow right at the intake and the storage right at Yamcolo Reservoir. It operates only after water has been released from Fish Creek Reservoir and Stagecoach Reservoir to satisfy the Steamboat Springs/Mt. Werner demand. The amount of water released to the direct diversion is restricted by the amount currently available in the account, unsatisfied demand at the Fish Creek Municipal Intake, and available flow from the headgate to the confluence of Fish Creek with the Yampa River.

In the first calibration run, operating right 24 releases water to meet the historical end-of-month content if modeled contents are above that value after all demand-based releases occur. The junior administration number ensures this is the last operating right to fire. It is turned OFF in the baseline data set.

5.8.3 Allen Basin Reservoir

Allen Basin Reservoir (WDID 583500) is a small irrigation reservoir located near the headwaters of Middle Hunt Creek. Although it is smaller than the minimum reservoir capacity (4,000 acre-feet) generally used for inclusion in the Yampa model, it is modeled explicitly because it plays a significant role in the irrigation water supply in this water-limited area of the Yampa River basin. The reservoir has a decreed capacity of 2,250 af, which is also reported to be its active capacity.

Storage water in Allen Basin Reservoir provides supplemental irrigation supplies to several direct flow structures in the Hunt Creek drainage. Using information provided by the Water Commissioner, the ownership sub-accounts are combined into a single pool (2,250 acre-feet) in the reservoir:

Account	Owner	Capacity (acre-feet)
1	AGGREGATED POOL	2,250

Six operating rights are used to simulate Allen Basin Reservoir activities. The first four rights control releases to the various irrigators owning shares in the reservoir. The fifth right is the requisite release-to-target right for calibration. The last right relates to filling the reservoir from South Hunt Creek. Since the fill affects both a diversion station and the reservoir station, an operating right is required:

Right #	Destination	Reservoir Account	Admin #	Right Type	Description
1	Collins Ditch	1	39254.37914	2	Release to direct diversion
2	Simon Ditch	1	39254.37914	2	Release to direct diversion
3	Lateral A Ditch	1	39254.37914	3	Release to direct diversion
4	Mill Creek Ditch	1	40753.00001	3	Release to direct diversion
5	Allen Basin Resvr to Target	1	99999.99999	9	Res to River by Target
6	Allen Basin Reservoir	1	39254.37914	11	Direct diversion to reservoir through an intervening structure

Operating right 1 releases water from account 1 to the Collins Ditch (580591). The administration number for this operating right is just junior to the direct flow right for the Allen Basin Supply ditch, and also junior to several Collins Ditch direct flow rights. The amount of water released to Collins Ditch is limited by the amount currently available in the account, and unsatisfied demand at the ditch.

Operating right 2 releases water from account 1 to the Simon Ditch (580863). The administration number for this operating right is just junior to the direct flow right for the Allen Basin Supply ditch, and also junior to several Simon Ditch direct flow rights. The amount of water released to Simon Ditch is limited by the amount currently available in the account, and unsatisfied demand at the ditch.

Operating right 3 releases water from account 1 to the Lateral A Ditch (580730). The administration number for this operating right is just junior to the direct flow right for the Allen Basin Supply ditch, and also junior to several Lateral A direct flow rights. The amount of water released is limited by the amount currently available in the account, and unsatisfied demand at the ditch.

Operating right 4 releases water from account 1 to the Mill Creek Ditch (581085). The administration number for this operating right is just junior to the direct flow right for the Allen Basin Supply ditch, and also junior to several Mill Creek Ditch direct flow rights. The amount of water released is limited by the amount currently available in the account, and unsatisfied demand at the ditch.

Operating right 5 is turned OFF in the baseline data set. In the first calibration step, it releases water to meet the historical end-of-month content if modeled contents are above historical levels after all demand-based releases occur. The junior administration number ensures this is the last operating right to fire.

Operating right 6 supplies water to Allen Basin Reservoir from South Hunt Creek via the Allen Basin Supply Ditch (580506). The amount of water transferred is limited by decreed amount and legally available flow under the Allen Basin Supply Ditch's single direct flow right on South Hunt Creek. Allen Basin Reservoir also has a "regular" storage right to native flows on Middle Hunt Creek, which fires before this right.

5.8.4 Stagecoach Reservoir

Stagecoach Reservoir provides supplemental municipal and industrial water supplies, as well as a significantly sized conservation pool for recreational purposes. The reservoir is represented in the model as having the four pools listed below. History and ownership of these pools are described in Section 5.6.1.3.3.

Account	Owner	Capacity (acre-feet)
1	INDUSTRIAL	11,000
2	MUNICIPAL POOL	4,000
3	RECREATION POOL	15,000
4	DEAD POOL	3,275

Four rights specify Stagecoach operations in the model:

Right #	Destination	Reservoir Account	Admin #	Right Type	Description
1	Craig Station (Tri-State)	1	45290.44866	2	Release to direct diversion
2	Fish Creek Municipal Intake	2	42156.00002	4	Release to diversion by exchange
3	Stagecoach Hydropower	1	50769.48499	2	Release to direct diversion
4	Stagecoach Resvr to Target	1 through 3	99999.99999	9	Res to River by Target

Operating right 1 releases water from account 1 to the Craig Power Station (440522). The administration number for this operating right is junior to both the direct flow right at the Craig Station and the storage right at Stagecoach Reservoir. The amount of water released to the direct diversion is restricted by the amount currently available in the account, and unsatisfied demand at Craig Station.

Operating right 2 releases water from account 2 to allow diversion by exchange at the Fish Creek Municipal Intake. The administration number for this operating right is junior to both the direct flow right at the intake and the storage right at Stagecoach Reservoir. The right fires ahead of releases from the municipal account in Yamcolo Reservoir, which can also satisfy the Fish Creek municipal demand by exchange. The amount of the diversion and release is limited by the amount of water available in the account, unsatisfied demand, and legally available flow from the Fish Creek headgate downstream to the confluence of Fish Creek with the Yampa River

Operating right 3 simulates releases from storage through UYWCD's hydroelectric generating facility on the outlet works of Stagecoach Dam. The hydropower plant can produce electricity from both bypassed inflows and reservoir releases. During initial simulations, there were significant errors in the gage below Stagecoach Reservoir. Since diversion records exist for the power facility, these diversions were added to the model as a non-consumptive demand that could be satisfied first by the plant's rather junior direct flow right, and then by operating this right. This configuration resulted in improved agreement between simulated and historical gage values, and probably represents operations that are carried out incidentally to the primary purposes of the reservoir.

Operating right 4 is turned OFF in the baseline data set. In the first calibration step, it releases water to meet the historical end-of-month content if modeled contents are above historical levels after all demand-based releases occur. The junior administration number ensures this is the last operating right to fire.

5.8.4 Lake Catamount

Lake Catamount Reservoir (WDID 583631) was built primarily for recreation for the planned residential and ski development near the lake. To date, that use has not developed. According to the Division 6 engineer and water commissioner, the reservoir is normally operated to keep it full. Historically, there has been a practice to lower the reservoir by releasing approximately 2,000 acre-feet in October to protect against the formation of frazil ice near the reservoir inlet during the winter months. The model includes only one account and one operating right for Lake Catamount.

Account	Owner	Capacity (acre-feet)
1	CONSERVATION POOL	7,422

Right #	Destination	Reservoir Account	Admin #	RightType	Description
1	Lake Catamount to Target	1	99999.99999	9	Res to River by Target

Operating right 1 is turned ON in the baseline data set, unlike the similar rights at other reservoirs in the Yampa model. The maximum monthly targets for Lake Catamount reflect the pre-winter lowering of the reservoir, followed by a slow fill through the winter. This right causes Lake Catamount to release about 2,000 af in October, and reservoir storage rights affect the winter filling.

5.8.6 Fish Creek Reservoir

Fish Creek Reservoir (WDID 583508) is owned by the city of Steamboat Springs and is used as reserve raw water storage for the city and for the Mt. Werner Water & Sanitation District. According to city personnel, the direct flow rights are generally sufficient to satisfy the demand through the end of July. At that time, the physical supply in Fish Creek begins to decrease and it is necessary to supplement the direct flow diversions with water released from storage in Fish Creek Reservoir. Fish Creek Reservoir is modeled with a single account.

Account	Owner	Capacity (acre-feet)
1	STEAMBOAT SPRINGS/MT. WERNER WSD	4,042

Two operating rights are used to simulate Fish Creek Reservoir's operations:

Right #	Destination	Reservoir Account	Admin #	Right Type	Description
1	Fish Creek Municipal Intake	1	42156.00000	2	Release for direct diversion
2	Fish Creek Resvr to Target	1	99999.99999	9	Res to River by Target

Operating right 1 releases water from account 1 to the downstream Fish Creek Municipal Intake (580642). The administration number for this operating right is junior to the multiple direct flow rights at the Fish Creek Municipal Intake, and senior to releases from Stagecoach and Yamcolo Reservoirs for diversion by exchange. This right fires after two of three storage rights at Fish Creek Reservoir. The amount of the release is limited by the amount currently available in the account, and unsatisfied demand at the Fish Creek Municipal Intake.

Operating right 2 is turned OFF in the baseline data set. In the first calibration step, it releases water to meet the historical end-of-month content if modeled contents are above historical levels after all demand-based releases occur. The junior administration number ensures this is the last operating right to fire.

5.8.7 Steamboat Lake Reservoir

Steamboat Lake (WDID 583787) is used primarily for recreational purposes, and as back-up supply for the Hayden power station. These purposes are reflected in the reservoir's two modeled accounts:

Account	Owner	Capacity (acre-feet)
1	HAYDEN STATION	5,000
2	CONSERVATION POOL	21,364

Two operating rights are used to simulate Steamboat Lake:

Right #	Destination	Reservoir Account	Admin #	RightType	Description
1	Hayden Station	1	51134.4323	2	Release for direct diversion
2	Steamboat Lake to Target	1	99999.99999	9	Res to River by Target

Operating right 1 releases water in account 1 when the direct flow rights decreed for operating the Hayden Station (570512) are insufficient to satisfy demand at the power plant. The administration number for this operating right is junior to both the direct flow rights for Hayden Station, and the storage rights at the reservoir. The amount of the release is limited by the amount currently available in the account, and unsatisfied demand at the diversion.

Operating right 2 is turned OFF in the baseline data set. In the first calibration step, it releases water to meet the historical end-of-month content if modeled contents are above historical levels after all demand-based releases occur. The junior administration number ensures this is the last operating right to fire.

5.8.8 Lester Creek Reservoir

Lester Creek Reservoir (WDID 583521, aka Pearl Lake) is located on Lester Creek, a tributary of the Elk River downstream of Steamboat Lake. The reservoir is owned and operated by CDOW and used exclusively for recreational and fishery purposes. It is modeled with a single account and a single operating right:

Account	Owner	Capacity (acre-feet)
1	CONSERVATION POOL	5,657

Right #	Destination	Reservoir Account	Admin #	Right Type	Description
1	Lester Creek Resvr to Target	1 through 3	99999.99999	9	Res to River by Target

Operating right 1 is turned OFF in the baseline data set. In the first calibration step, it releases water to meet the historical end-of-month content if modeled contents are above historical levels after all demand-based releases occur. The junior administration number ensures this is the last operating right to fire.

5.8.9 Elkhead Creek Reservoir

Elkhead Creek Reservoir (WDID 443902) is located on Elkhead Creek, a tributary of the Yampa River, just upstream of the city of Craig. Bases for the three accounts in Elkhead Reservoir are explained in Section 5.6.1.3.9.

Account	Owner	Capacity (acre-feet)
1	CRAIG STATION DITCH & P/L	8,408
2	CRAIG WATER SUPPLY PIPELINE	4,413
3	CWCB	5,000
4	CRWCD	6,957

Three rights are used to simulate Elkhead Creek Reservoir:

Right #	Destination	Reservoir Account	Admin #	Right Type	Description
1	Craig Station (Tri-State)	1	45290.44866	2	Release to direct diversion
2	Craig Water Supply Pipeline	2	42156.00002	2	Release to direct diversion
3	Endangered Fish Critical Habitat Reach	3	99998.99999	1	Release to minimum flow
4	Elkhead Resvr to Target	1 through 3	99999.99999	9	Res to River by Target

Operating right 1 supplies industrial water to satisfy shortages at the Craig Station Units 1 and 2 after the senior direct flow rights have been diverted through the Craig Station Ditch and Pipeline (440522). The administration number for this operating right is junior to both the direct flow right at the diversion and the storage right at the reservoir. It is equivalent to the administration number for the release from Stagecoach Reservoir. The amount of the release is restricted by the amount currently available in the account, and unsatisfied demand at Craig Station.

Operating right 2 supplies storage water to satisfy shortages to the City of Craig's municipal demand after the City's direct flow water rights on the Yampa River have been exercised. The administration number for this operating right is junior to both the direct flow right at the diversion and the storage right at the reservoir. The amount of water released to the Craig Water Supply Pipeline is restricted by the amount currently available in the account, and unsatisfied demand.

Operating right 3 releases water from the CWCB account to when flows near the Maybell gage drop below 300 cfs, from August through October. The release is limited to the minimum of account contents and the deficit to the target flow. The administration number is very junior.

Operating right 4 is turned OFF in the baseline data set. In the first calibration step, it releases water to meet the historical end-of-month content if modeled contents are above historical levels after all demand-based releases occur. The junior administration number ensures this is the last operating right to fire.

5.8.10 High Savery Reservoir

High Savery Reservoir (WDID 993002) is located on Savery Creek, a north side tributary of the Little Snake Rivernear in Wyoming. The reservoir has a capacity of 22,433 af, and provides a supplemental supply to downstream irrigators..

Storage water in High Savery Reservoir provides supplemental irrigation supplies to many downstream irrigators. These users are represented in the Yampa model in aggregate structures. Wyoming's model of the Little Snake basin, developed for the Little Snake River Supplemental Storage Study, was relied on to identify the project beneficiaries, order of operations, and switch settings.

Account	Owner	Capacity (acre-feet)
1	IRRIGATION POOL	22,433

Eleven operating rights are used to simulate High Savery Reservoir releases.

Right #	Destination	Reservoir Account	Admin #	Right Type	Description
1	WYD_006	1	55304.00000	2	Release to direct diversion
2	WYD_007	1	55306.00000	2	Release to direct diversion
3	WYD_010	1	55307.00000	2	Release to direct diversion
4	540583	1	55308.00000	2	Release to direct diversion
5	54_ADY023	1	55309.00000	2	Release to direct diversion
6	540531	1	55311.00000	2	Release to direct diversion
7	540594	1	55313.00000	2	Release to direct diversion
8	WYD_005	1	55315.00000	2	Release to direct diversion
9	WYD_002	1	55317.00000	4	Release to diversion by exchange
10	WYD_003	1	55318.00000	2	Release to direct diversion
11	WYD_004	1	55320.00000	4	Release to diversion by exchange

All operating rights releases water from account 1. The administration numbers for the operations are generally junior to the direct flow rights for the destination structures. The deliveries by exchange (rights 9 and 11) are currently turned off as they are in Wyoming's model.

6. Baseline Results

The "Baseline" data set simulates current demands, current infrastructure and projects, and the current administrative environment, as though they had been in place throughout the modeled period. This section summarizes the state of the river as the Yampa model characterizes it, under these assumptions.

6.1 Baseline Streamflows

Table 6.1shows, for each gage, the average annual flow from the Baseline simulation, based on the entire simulation period (1909 – 2005). In general, this value is presumably a little lower than the historical average, because demand has risen and the development of storage has re-timed the supply so that more of the demand can be met. The second value in the table is the average annual available flow, as identified by the model. Available flow at a point is water that is not needed to satisfy instream flows or downstream diversion demand; it represents the water that could be diverted by a new water right. The available flow is always less than the total simulated flow.

Figure 6.1 illustrates the average annual simulated gage flow and available flow, in geographic context. Two bars are shown at each gage location. The bar on the left represents total simulated gage flow, and the bar on the right represents the available flow.

Temporal variability of the historical and Baseline simulated flows is illustrated in Figures 6.2 through 6.7. Each figure shows two graphs: an average annual hydrograph based on the entire modeling period; and overlain hydrographs of historical gage flow, simulated gage flow, and simulated available flow for 1975 through 2005. The annual hydrograph is a plot of monthly average flow values, for the three parameters. The gages selected for these figures have a fairly complete record between 1975 and 2005.

In general, Baseline flows are slightly lower than historical flows and exhibit the same monthly distribution. The exception is the gage below Stagecoach Reservoir, which is directly impacted by operations at Stagecoach. The historical gage averages reflect 14 years before the reservoir came online, and therefore show a more unregulated hydrograph than the simulated gage. In the simulation, Stagecoach Reservoir operates throughout the averaged period.

Table 6.1
Simulated Baseline Average Annual Flows for Yampa River Gages

Gage ID	Gage Name	Simulated Flow (af)	Simulated Available Flow (af)
09236000	Bear River Near Toponas	28,401	3,113
09237500	Yampa River Below Stagecoach Reservoir	57,959	26,353
09238900	Fish Creek At Upper Station	45,633	44,786
09239500	Yampa River At Steamboat Springs	320,583	277,160
09241000	Elk River At Clark	240,615	176,762
09244410	Yampa River Below Diversion near Hayden	723,081	690,376
09245000	Elkhead Creek Near Elkhead	42,644	40,529
09245500	North Fork Elkhead Creek	14,053	13,573
09246920	Fortification Creek near Fortification	7,733	7,484
09247600	Yampa River Below Craig	905,903	872,900
09249000	East Fork Of Williams Fork	82,598	73,858
09249200	South Fork Of Williams Fork	30,089	26,002
09249750	Williams Fork At Mouth	153,908	150,723
09251000	Yampa River Near Maybell	1,083,227	995,299
09253000	Little Snake River Near Slater	159,256	150,001
09255000	Slater Fork Near Slater	57,018	54,900
09255500	Savery Creek near Upper Station	36,188	28,797
09256000	Savery Creek near Savery	81,217	69,675
09257000	Little Snaker River Near Dixon	359,279	345,399
09258000	Willow Creek Near Dixon	7,139	4,091
09260000	Little Snake River Near Lily	402,319	401,661
9260050	Yampa River At Deerlodge Park	1,457,935	1,457,168

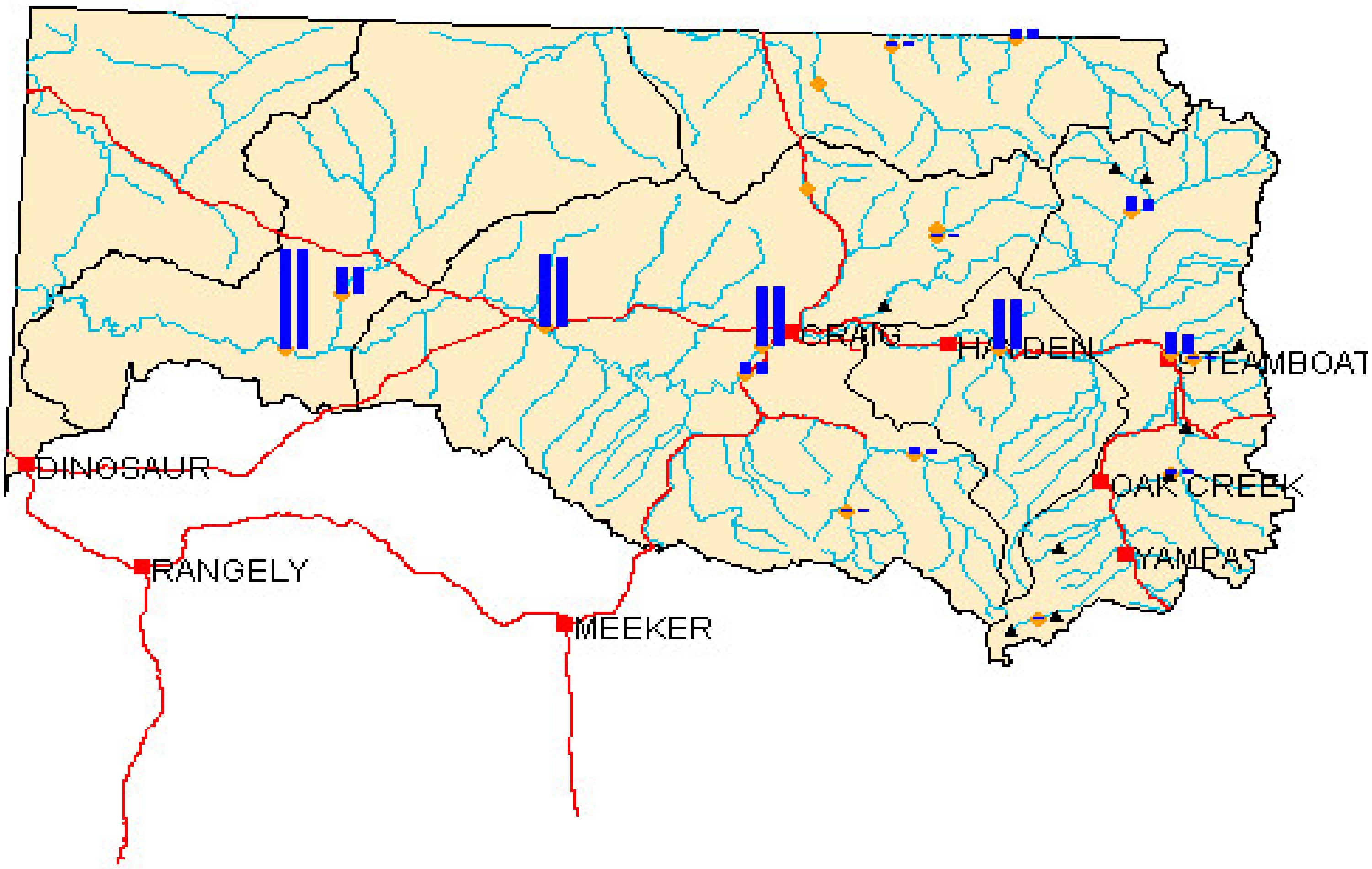
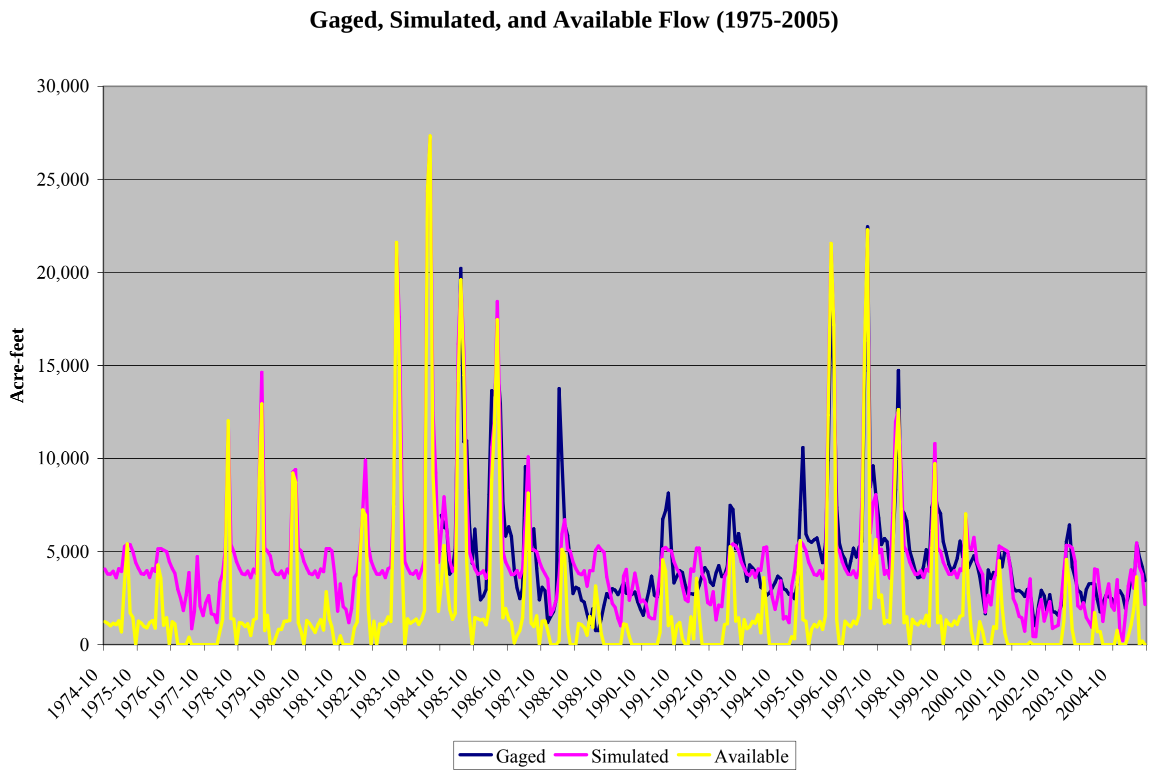


Figure 6.1 Average Annual Simulated Gage Flow (Left) and Average Annual Available Gage Flow (Right) at Yampa Model Gages



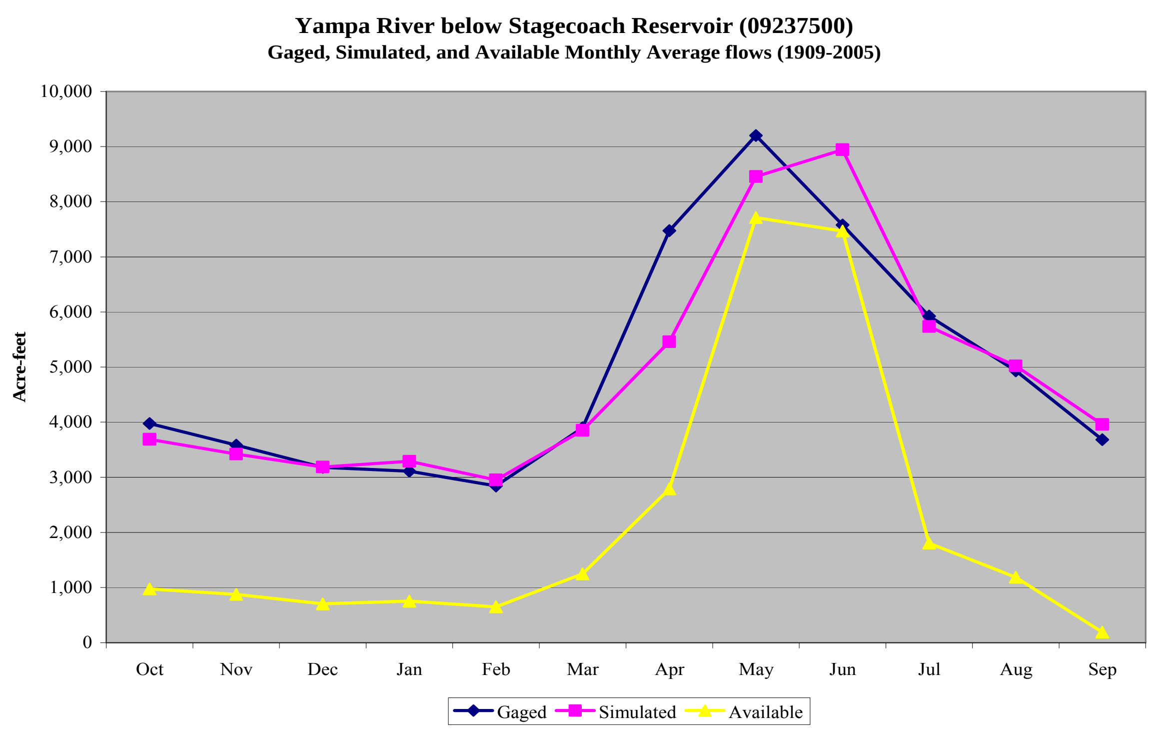
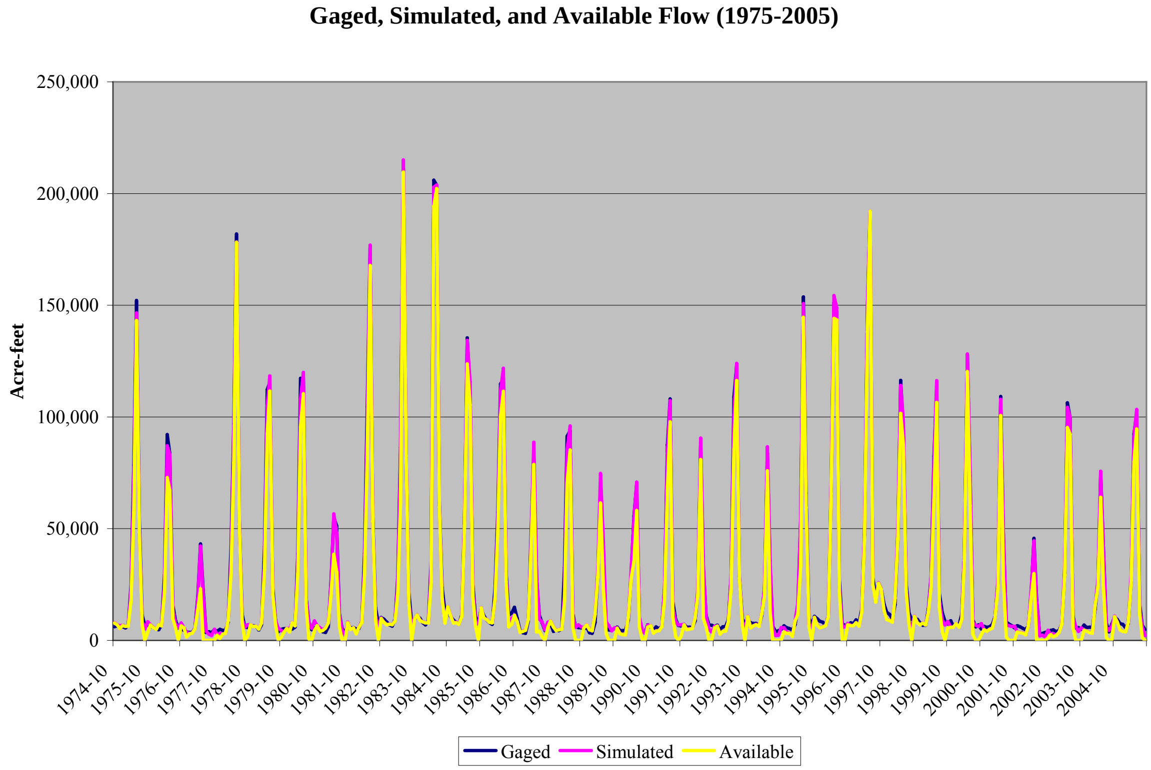


Figure 6.2 Gaged, Baseline Simulated, and Available Flows (Yampa River below Stagecoach Reservoir)



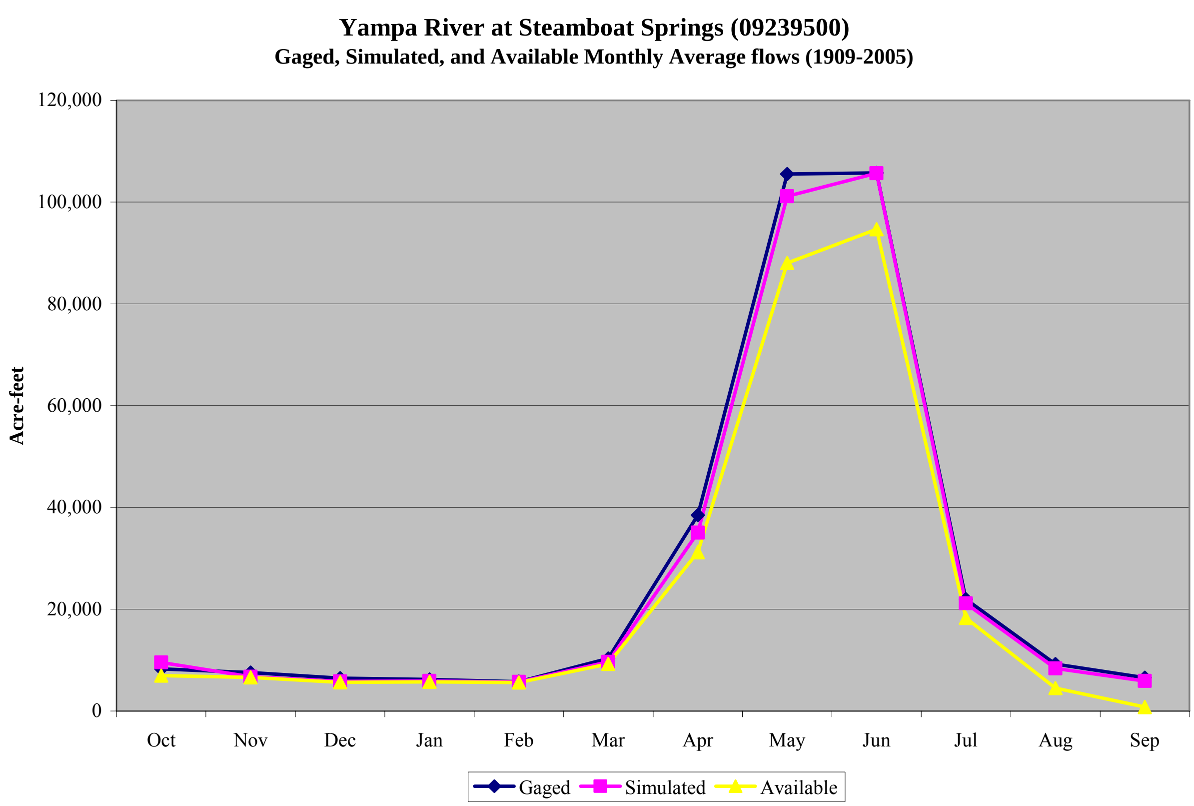
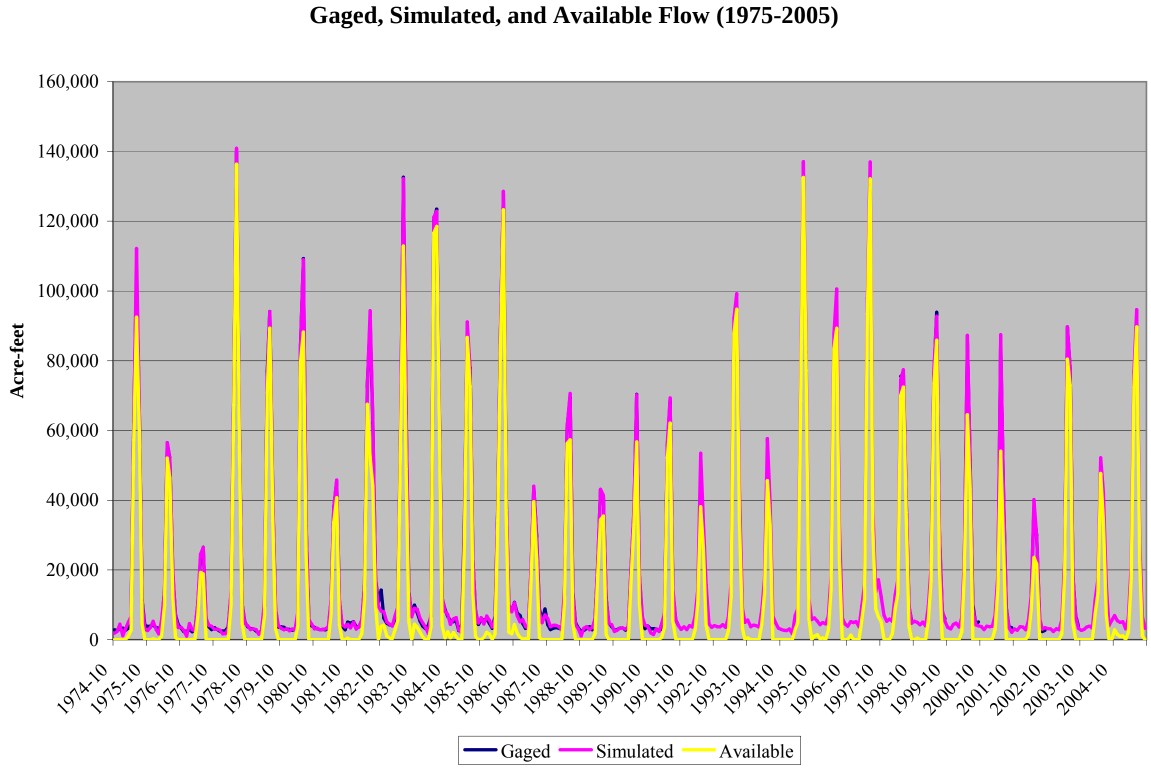


Figure 6.3 Gaged, Baseline Simulated, and Available Flows (Yampa River at Steamboat Springs)



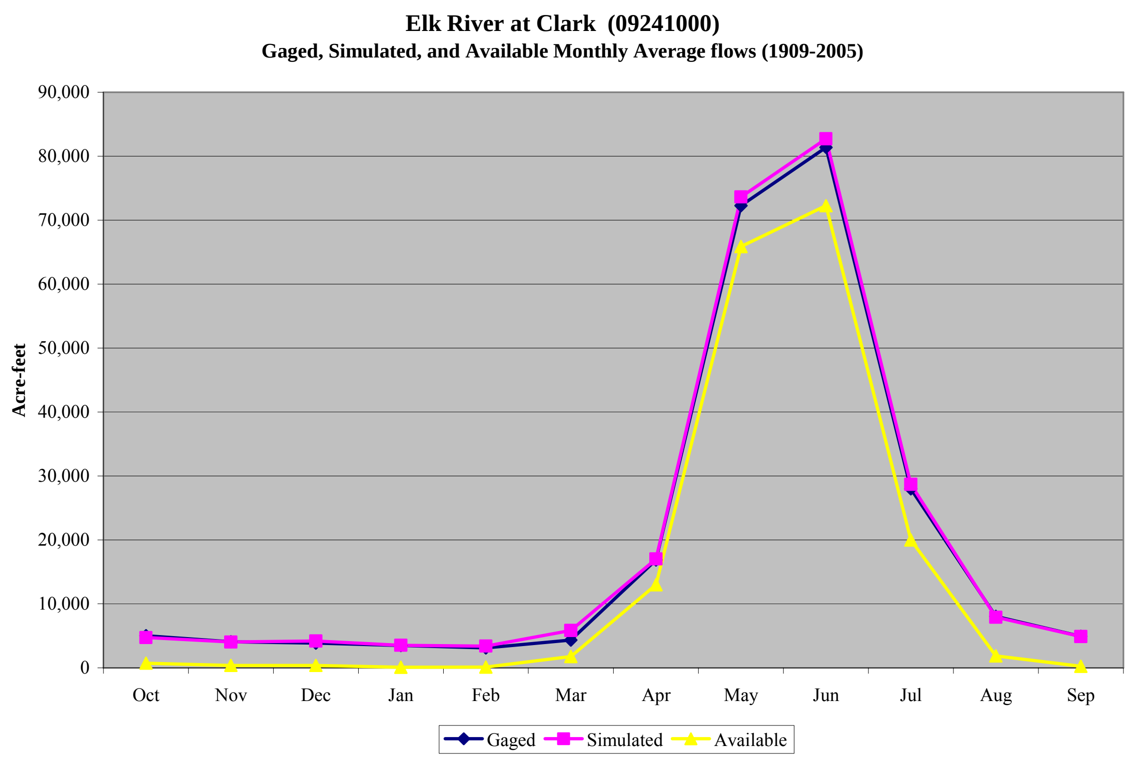
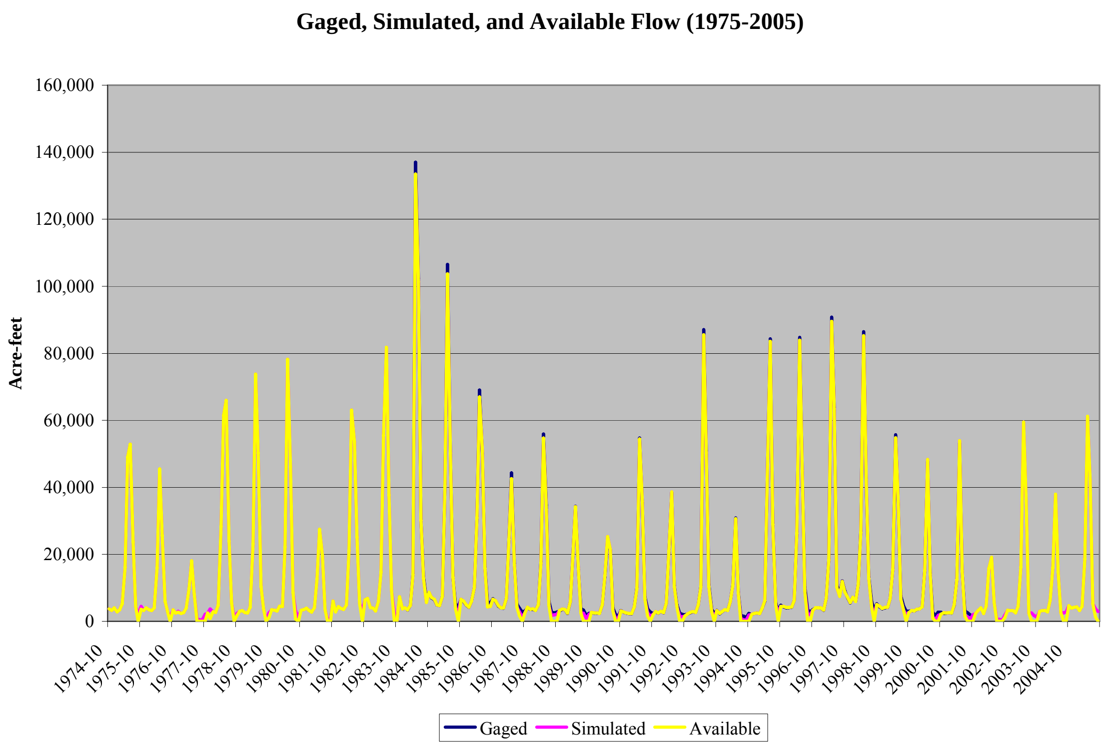


Figure 6.4 Gaged, Baseline Simulated, and Available Flows (Elk River at Clark)



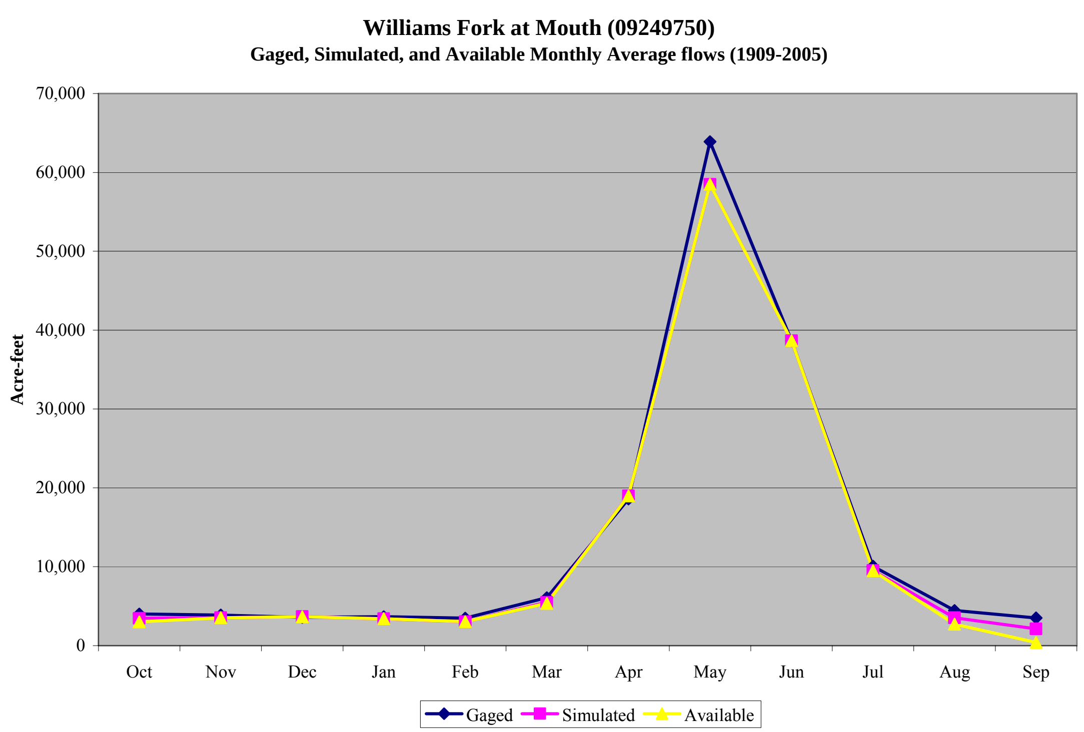
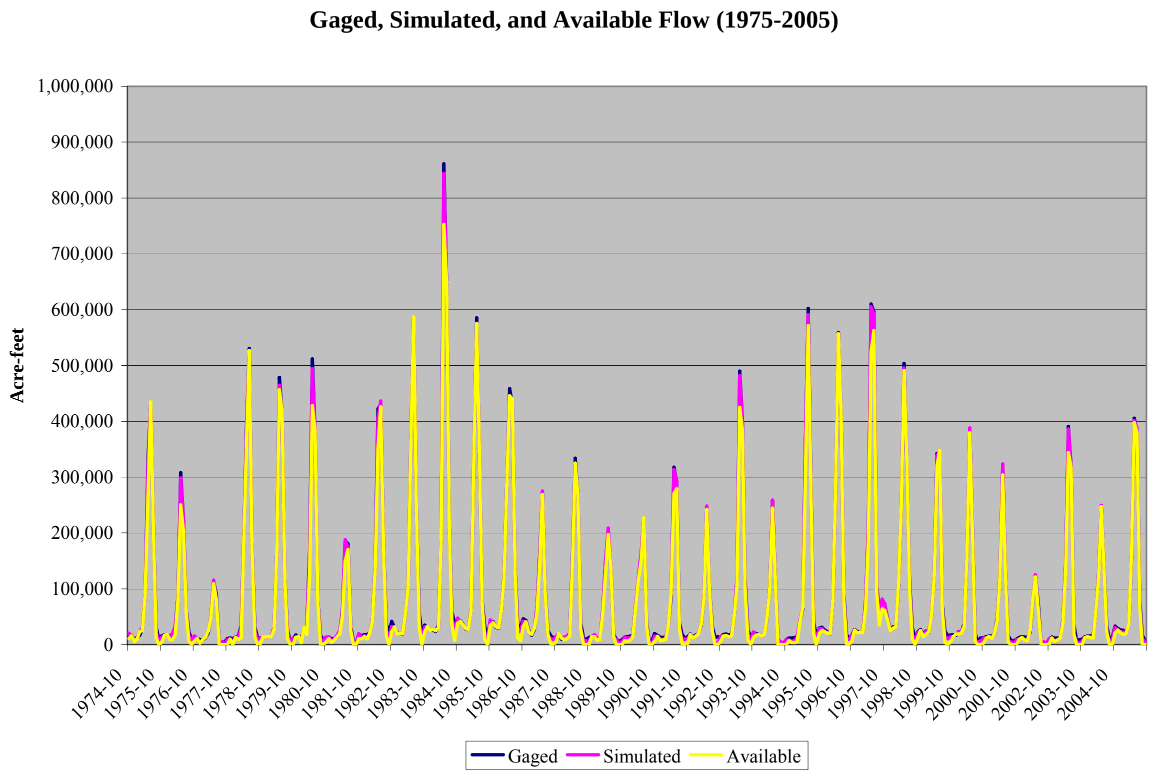


Figure 6.5 Gaged, Baseline Simulated, and Available Flows (Williams Fork at Mouth)



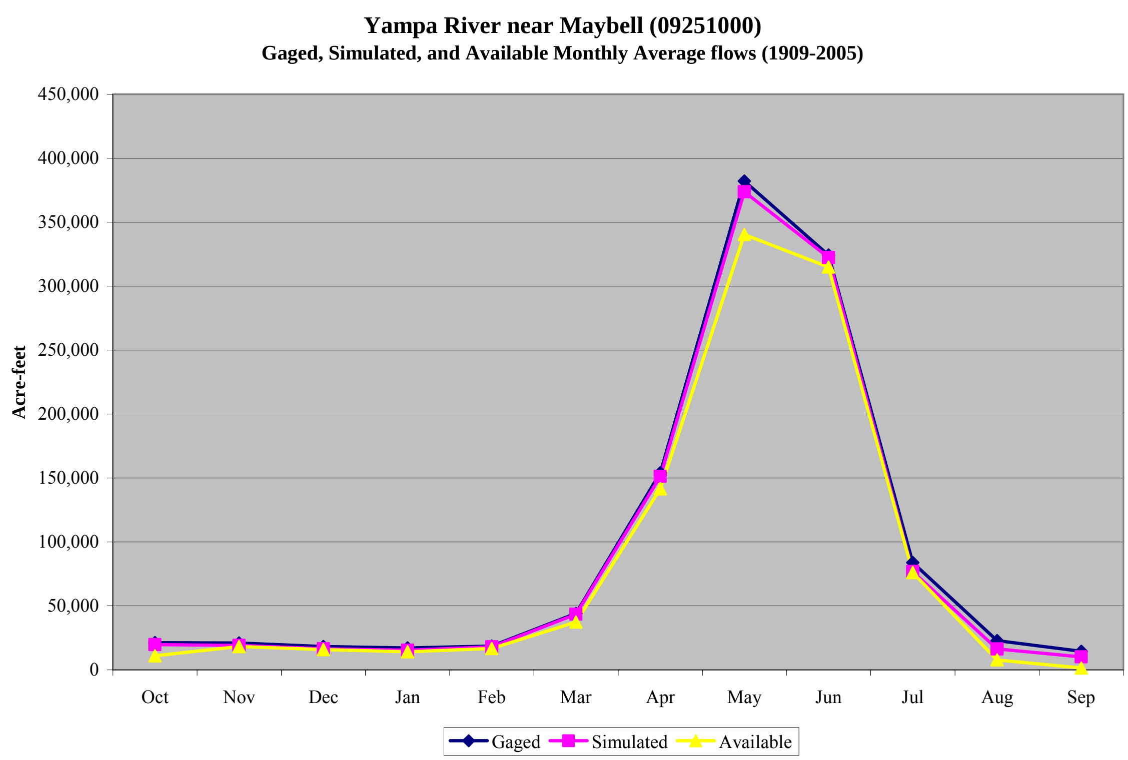
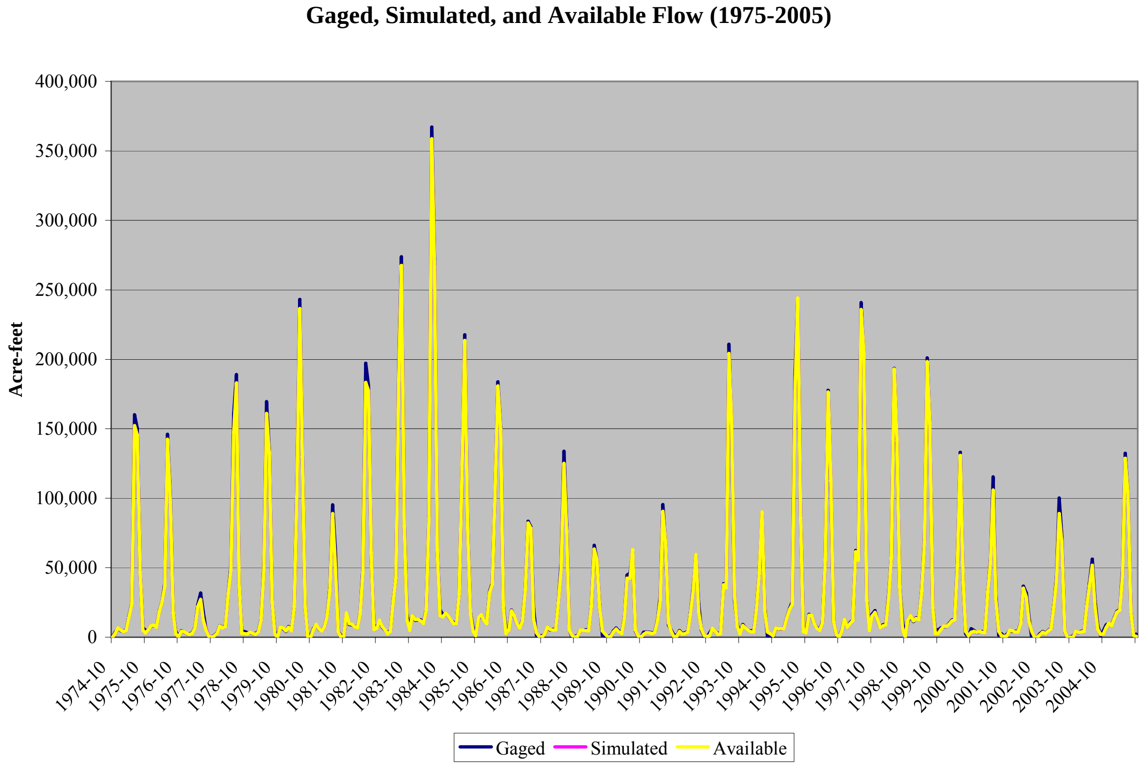


Figure 6.6 Gaged, Baseline Simulated, and Available Flows (Yampa River near Maybell)



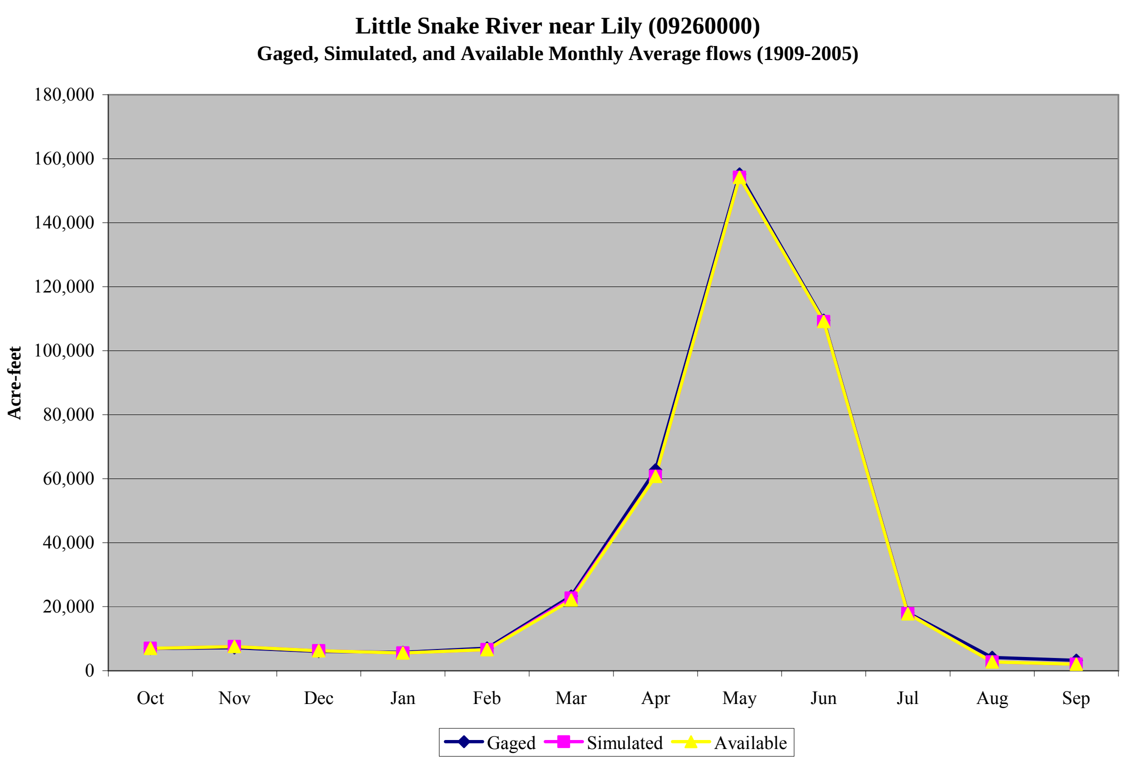


Figure 6.7 Gaged, Baseline Simulated, and Available Flow (Little Snake River near Lily)

7. Calibration

Calibration is the process of executing the model under historical conditions, and modifying estimated parameters to improve agreement between the model results and the historical record. This section describes the general approach taken in calibrating the Yampa model. It describes specific areas of the basin that were worked on, and it presents summaries comparing modeled results for 1975 through 2005 with historical values for the period.

7.1 Calibration Process

The Yampa model was calibrated in a two-step process, based on the period 1975 through 2005. In the first step, demands were set to historical diversions, and reservoir levels were constrained to their historical levels. Reservoir storage was limited to the historical monthly content for each month. Reservoirs released water upon demand, but if the demand-driven operations left more water in a reservoir than it had historically, the model released enough water to the stream to achieve its historical end-of-month contents. In this step, the basic hydrology was assessed, and in general, baseflow distribution parameters and return flow characteristics were modified.

Reviewing the model run consisted of comparing simulated gage flows with historical flows, and determining where and why diversion shortages occur. For example, a shortage might occur because a user's water right is limiting. But it might also occur because water is physically unavailable or the water right is called out. In this typical calibration problem, there may be too little baseflow in a tributary reach to support historical levels of diversion in the model. Baseflow at the next downstream gage may be modeled correctly, but stream gains have been modeled as entering the system further downstream than their actual point of entry, thereby shorting the tributary structure(s). Because the historical diversion and consumption do not occur in the model, the model then overestimates flow at the downstream gage. Baseflow distribution parameters must be adjusted such that more water enters the system within the tributary, and typically, incremental inflow below the tributary is reduced. The first step of calibration might also expose errors such as incorrect placement of a gage, or incorrect treatment of imports.

In the second step, operations were generalized. Reservoirs responded to demands, and were permitted to seek the level required to meet the demands. Model results were again scrutinized, this time focusing on the operations. For example, operating criteria in the form of monthly targets might be added for reservoirs that operate for unmodeled reasons such as flood control, hydropower generation, or winter maintenance. As another example, where reservoir history revealed that annual administration was not strictly observed, the annual administration feature was removed.

The model at the conclusion of the second step is considered the calibrated model.

7.2 Historical Data Set

Calibration is based on supplying input that represents historical conditions, so that resulting gage and diversion values can be compared with the historical record. This data set is referred to as the "Historical data set", and it is helpful to understand how it differs from the Baseline data set described in Section 5.

7.2.1 Demand file

A primary difference in data sets is the representation of demands *(*.ddm* file). For calibration, both irrigation and non-irrigation demands were set to historical diversions, to the extent they were known. Gaps in the diversion records were filled using the automatic data filling algorithm described in Section 4.4.2. This demand reflects both limitations in the water supply and the vagaries of operations that cannot be predicted – headgate maintenance, dry-up periods, and so on.

7.2.2 Reservoir Station File and Reservoir Target File

In the Historical data set, reservoirs are inactive prior to onset of their historical operations. Initial contents in the reservoir file (*.res) are set to zero (as they were historically in 1909), and storage targets (*.tar file) are set to zero until the reservoir actually began to fill. In the first calibration step, storage targets assume the value of the historical end-of-month contents, but in the second calibration step, storage targets are set to the reservoir's capacity as soon as the reservoir comes on-line. If capacity changed midway through the study period (e.g., Fish Creek Reservoir), the Historical model takes the enlargement into account.

7.3.3 Operational Rights File

The reservoir storage targets and the operating rules (the *.opr file) work together to constrain reservoir operations in the first calibration step. The operational rights include rules to release water that remains in the reservoir above historical levels (specified in the target file), after all demand-driven releases are made. In the second calibration step, release-to-target rules in the *.opr file are turned off for all reservoirs (except for Lake Catamount – see Section 5.6.4). In both calibration runs, when water is released to a downstream diversion, enough water is released to meet the diverter's historical diverted amount, regardless of the efficiency of that operation.

Differences between the Baseline data set and the Historical data set are summarized in Table 7.1.

Table 7.1
Comparison of Baseline and Historical (Calibration) Files

Input File	Baseline Data Set	Historical Data Set
Demand (*.ddm)	▪ Irrigation structures – "Calculated" demand for full supply, based on historical efficiency ▪ Non-irrigation structures – estimated current demand	▪ Historical diversions
Reservoir station (*.res)	▪ Initial content = full	▪ Initial content = 0.
Reservoir target (*.tar)	▪ Current maximum capacity	▪ First step – historical e/o/m contents, 0 prior to historical operation ▪ Second step – historical maximum capacity, 0 prior to historical operation
Operational right (*.opr)	▪ No release to target operations	▪ release to target operations

7.3 Calibration issues

This section describes areas of the model that have been investigated in the various calibrations of the Yampa model.

7.3.1 Stagecoach Reservoir

In preliminary model runs, simulated flows for the gage 092375000 Yampa River below Stagecoach Reservoir did not match historical flows in later years (1989 through 1996). The Stagecoach hydropower plant, a diversion structure with good historical records, was shorted in the Historical run. In the real world, the power plant can divert water from storage in Stagecoach Reservoir or under its direct flow right. To achieve better calibration, an operating rule to release from Stagecoach to the hydropower plant was added. It was assigned an administration number just junior to the direct flow right. Shortages at the power plant were significantly reduced and simulation of the gage below the reservoir improved appreciably.

7.3.2 Fish Creek Basin

Mass balance for the purpose of baseflow estimation above the Fish Creek gage yielded numerous negative values. The problem stemmed from the change in size of the reservoir when it was enlarged in the mid-1990's. Normal CDSS data filling techniques for the historical end-of-month contents did not take this into account. Missing values throughout the study period were filled with average contents computed for the combined pre-enlargement and post-enlargement periods. An .stm file was built in which the pre-enlargement period was filled with the average pre-enlargement contents for the month, and the post-enlargement period was filled with the average post-enlargement contents for the month. This refinement improved both the balance above the Fish Creek gage, and the baseflow gain term for the gage reach bounded downstream by the Steamboat Springs gage. The Fish Creek gage is one of the upstream gages for this reach.

Several other changes were made to improve simulation of Fish Creek Reservoir and the gage below it. Conditional rights for Fish Creek Reservoir were added to the reservoir rights file by explicitly calling for them in the **StateDMI** command file. If the rights have been perfected, Hydrobase does not currently reflect that, so the reservoir was not storing to its capacity in the post-enlargement period. Secondly, earlier versions of the model had the P*A term for Fish Creek Reservoir equivalent to that term for the Fish Creek gage. In fact, the reservoir catchment is about one-fifth the size of the gage catchment. Under the previous settings, there was always plenty of supply to the reservoir and the Mt.Werner/Steamboat Springs intake, which draws on Fish Creek Reservoir for supplemental supply. Fish Creek Reservoir barely ever operated. More realistic P*A terms for Fish Creek Reservoir were supplied to the model, with the result that simulated reservoir contents, particularly in the most recent years when data were more complete, match historical contents much better.

Fish Creek Reservoir, according to the historical record, regularly stores more than its decreed capacity during the peak runoff month. In the model, storage is never allowed to exceed the nominal physical capacity or decreed amount. As a result, the simulated downstream gage tends to be high in May or June, because the simulated reservoir stops storing before the actual reservoir stops storing. Reservoir targets and capacity could have been altered to improve simulation of the gage, but that would have been inconsistent with CDSS's objective of representing existing legal constraints.

7.3.3 Fortification Creek Basin

Fortification Creek was investigated because structures were initially shorted by between 8 and 40 percent in the calibration runs. It was determined that both the network location and baseflow parameters for gage 09246920 Fortification Creek near Fortification needed to be changed. The gage had been erroneously placed in the network below Little Cottonwood Creek, but is actually some distance above it. Area and precipitation terms for 09246920 were set to 63 square miles and 17 inches, respectively, based on the CDSS Yampa GIS and confirmed by the USGS Water Resources Data publication. Baseflows at several Fortification basin headwater nodes were modified to use the neighboring gage approach based on the Elkhead Creek gage. Structures in the Fortification Creek basin were positively impacted, several having reduced shortages by more than 20 percentage points, relative to the preceding calibration run. The gage simulation is within 2 percent in each year of its short period of operation (1985-1991), compared with annual differences of as much as 11 percent in the earlier model.

7.3.4 Williams Fork Basin

There were significant shortages in this basin in the original calibration runs. On Morapos Creek in particular, shortages initially ranged from 30 to 60 percent for all structures. The gage at the mouth of Williams Fork showed an inordinately large gain, indicating that the distribution of baseflows to ungaged locations was not accurate. The neighboring gage approach was then selected for the headwater nodes on Morapos, Deer, Pine, and Waddle Creeks, using the baseflow at Williams Fork at Mouth (09249750) for the Area*Precipitation proration. This was done without inducing an incremental baseflow loss at the mouth gage, at least on an average annual basis.

Shortages on Waddle, Deer, and Pine Creeks were significantly reduced, and shortages on Morapos Creek were relieved although less dramatically. Calibration of the Williams Fork gage at the mouth of the river improved slightly, so the change was adopted.

7.3.5 Milk Creek Basin

All eleven structures in this tributary basin experienced shortages of between 10 and 45 percent in initial configurations of the model. After some experimentation, baseflow at the headwater node 440692 was determined using the neighboring gage approach, based on 09249750 Williams Fork at the MouthIn addition, the area and precipitation parameters were enlarged to include the area from 440692 down to 44_ADY017. With the new configuration, diversion shortages on the mainstem of Milk Creek were eliminated, although there are still shortages on the two side tributaries.

7.3.6 Little Snake Basin

These calibration issues relate to the development phase in which the Wyoming portion of the Little Snake basin was added to the model, using information from the State of Wyoming's Green River Basin Plan and Little Snake River spreadsheet model.

Initially, the mass balance for the purpose of estimating baseflow at the Lily gage produced many negative values, primarily in dry Octobers. The previous version of the model featured fairly high October diversions in Wyoming, based on the U.S. Bureau of Reclamation's CULR annual figures, distributed to monthly. Therefore, there were enough diversions to add to the gaged flow to boost the baseflow positive even when the gage was very low or zero. However, both the GRBP consumptive use analysis and GRBP diversion records showed no October diversions in this area at all. After reviewing the GRBP, the following adjustments were made sequentially to reduce October return flows and improved the baseflow estimation above the Lily gage:

1. According to GRBP, most structures irrigate only 6 days in August and 5 days in September. Historical diversions (which had heretofore been estimated as crop irrigation requirement divided by .55, the maximum efficiency used in GRBP) for Wyoming aggregates below Baggs were recomputed for August and September , multiplying each by a fraction representing irrigation days as a fraction of the entire month (6/31 for August and 5/30 for September).

2. The same adjustment was made to Wyoming aggregates above Baggs.

3. Incidental losses below Baggs were changed from 3 percent to 10 percent. This change was made to both Wyoming and Colorado structures. Changing only the first month of the return flow pattern had virtually no impact on October return flows, as October diversions were nearly all zero. The 10 percent loss was next characterized as 7 percent occurring in the first month of the return, and 3 percent occurring in the second month. While high losses are credible in this area, it is believed that these are more related to delivery and overland or tailwater returns, rather than groundwater returns, so the loss was not "pushed" into the second month, even though that would have helped the balance.

These adjustments reduced the number of occurrences of negative baseflows, and their magnitudes, but it did not eliminate them. Furthermore, there were many months when the baseflow gain between 09257000 Little Snake River near Dixon and 09260000 was negative. The one headwater node in this reach, WYD_009 (headwater node on Muddy Creek), was assigned zero flow in these months. Therefore, a “setprfgage” command was added to the **StateDMI** command file to supply positive flows in the upper reaches of this basin. Every available Little Snake gage was checked to find the one that would generally produce the smallest amount of flow on Muddy Creek. Gage 09255500 Savery Creek near Upper Station was selected, although it probably results in higher simulated than actual flows on Muddy Creek.. To reduce the amount of water entering the mainstem from Muddy Creek, the lowest node on Muddy Creek (993003) was made a baseflow point. Area was taken from the drainage area of a short term USGS gage near the mouth of Muddy Creek, and precipitation was estimated based on surrounding precipitation terms and field observations of the basin.

July and August shortages in the upper Little Snake were occurring because water was being bypassed to meet Westside and First Mesa demand. Those structures would sweep the river, but then the baseflow gain would enter the stream at the Dixon gage (09257000), which was simulating higher than actual. Several steps were taken in succession:

1. WYD_006 was made a baseflow point so that WYD_006, First Mesa, and Westside would have access to the gain at the Dixon gage. The structures are all very close to the gage.

2. The return flow point for Westside Canal had been WYD_011, after the GRBP spreadsheet model. GRBP didn’t have the aggregated Colorado node 54_ADY023 as an option for the return location, and review of the mapping indicated that it would be appropriate to make the returns available to the Colorado aggregate.

3. Priority of Westside Canal, First Mesa Canal, WYD_007, WYD_009, and WYD_011 was lowered, to be junior to most Slater and Willow Creek rights (other than an enlargement or two). Since Wyoming administration numbers are not available and/or consistent with Colorado’s, previous versions of the model simply endowed Wyoming structures with rights that were senior to Colorado rights in the Little Snake, to prevent Colorado rights from calling out the Wyoming rights. This approach proved detrimental to the upper tributaries that come out of Colorado, and was therefore modified.

Structures on Willow Creek remained shorted because of physical availability. The Willow Creek Ditch (540591) was particularly shorted. In previous versions of the model, it had been made a baseflow node. In the context of the previous version’s hydrology, this placed more water in Willow Creek most of the time. In this model, because the Dixon gage was added to the model, and because the late season diversions in Wyoming were so different, there were many more baseflow losses below the Willow Creek gage and the Lily gage, and the baseflow node at the Willow Creek Ditch served at critical times to reduce flow rather than add to it. Therefore, the node was changed so that it is no longer a baseflow node. This improved shortages but did not eliminate them. Further review revealed that the Willow Creek Ditch’s historical diversion records are often higher than baseflow at the gage, which is just hundreds of feet upstream. Relative locations of the ditch and the gage were confirmed in a conversation with Bob Plaska (Division Engineer, Division 6). The discrepancy can be attributed to few observations at the headgate and the State’s carry forward filling method.

7.3.7 Reservoir Administration

Review of historical reservoir operations during calibration led to a conclusion that annual limits on reservoir storage are not strictly administered in the Yampa basin. Originally, reservoirs were assumed to have an administrative year beginning in November. With this parameter, the model showed reservoir storage being curtailed relatively early in the runoff period, so it was changed to April. Curtailment still occurred more often than is supported by the record of reservoir contents, so the annual administration was turned off.

7.4 Calibration Results

Calibration of the Yampa River model is considered very good, with all streamflow gages deviating from historical values by one percent or less, on an average annual basis. More than half the diversion structures' shortages are at or below 1 percent on an annual basis, and the basinwide shortage is 1.6 percent per year, on average. Simulated reservoir contents are representative of historical values.

7.4.1 Water Balance

Table 7.2 summarizes the water balance for the Yampa River model, for the calibration period (1975-2005). Following are observations based on the summary table:

- Surface water inflow to the basin averages 2.07 million acre-feet per year, and surface water outflow averages 1.84 million acre-feet per year.
- Annual diversions amount to approximately 531,000 acre-feet on average.
- Approximately 212,000 acre-feet per year is consumed.
- The column labeled "Inflow – Outflow" represents the net result of gain (inflow, return flows, and negative change in reservoir and soil moisture contents) less outflow terms (diversions, outflow, evaporation, and positive changes in storage). The small values are due to rounding on a monthly basis and indicate that the model correctly conserves mass.

Table 7.2
Average Annual Water Balance for Calibrated Yampa River Model (af/yr)

Month	Inflow	Return	From Soil Moisture	Total Inflow	Diversions	Resvr Evap	Stream Outflow	Resvr Change	To Soil Moisture	Soil Moisture Change	Total Outflow	Inflow - Outflow	CU
OCT	38,957	16,685	882	56,524	17,210	1,348	37,684	-600	1,199	-317	56,524	0	6,304
NOV	33,612	8,325	0	41,936	5,266	-28	34,510	2,189	438	-438	41,936	0	1,488
DEC	27,342	6,371	0	33,713	5,001	-305	28,346	671	263	-263	33,713	0	1,578
JAN	27,190	5,555	0	32,745	4,998	-328	27,665	410	182	-182	32,745	0	1,558
FEB	33,771	4,557	0	38,328	4,558	-82	33,723	130	122	-122	38,328	0	1,414
MAR	85,260	4,373	0	89,633	5,437	640	83,009	547	228	-228	89,633	0	2,143
APR	239,288	8,003	823	248,113	13,973	1,606	229,737	1,974	1,729	-906	248,113	0	5,516
MAY	644,965	47,173	2,453	694,590	95,450	3,003	593,233	451	7,547	-5,095	694,590	0	32,074
JUN	633,254	90,404	1,576	725,234	172,867	4,268	548,450	-1,926	8,113	-6,537	725,234	0	58,796
JUL	213,301	70,298	5,449	289,048	120,237	4,123	161,357	-2,118	1,924	3,525	289,048	0	52,963
AUG	58,688	36,793	8,317	103,797	51,814	3,058	39,822	787	531	7,785	103,797	0	31,315
SEP	34,818	26,271	3,998	65,087	34,271	2,644	24,598	-425	1,193	2,805	65,087	0	17,158
AVG	2,070,446	324,807	23,498	2,418,750	531,081	19,947	1,842,133	2,090	23,469	28	2,418,750	1	212,308

Note: Consumptive Use (CU) = Diversion (Divert) * Efficiency + Reservoir Evaporation (Evap)

7.4.2 Streamflow Calibration Results

Table 7.3 summarizes the annual average streamflow for water years 1975 through 2005, as estimated in the calibration run. It also shows average annual values of actual gage records for comparison. Both numbers are based only on years for which gage data are complete. Differences between gaged and simulated average annual streamflows are within 1 percent. Figures 7.1 through 7.7 (at the end of this section) graphically present monthly streamflow estimated by the model compared to historical observations at key streamgages in both time-series format and as scatter graphs. The goodness of fit is indicated on the scatter plot by the equation for the "best fit" regression line relating simulated to gage values. A perfect fit would be indicated by an equation "y = 1.000 * x".

Table 7.3
Historical and Simulated Average Annual Streamflow Volumes (1975-2005)
Calibration Run (acre-feet/year)

Gage ID	Historical	Simulated	Historical minus Simulated		Gage Name
			Volume	Percent	
9236000	29,633	29,454	179	1	Bear River Near Toponas
9237500	56,378	56,386	-8	0	Yampa River Below Stagecoach Reservoir
9238900	44,921	45,165	-243	-1	Fish Creek At Upper Station
9239500	316,784	316,770	14	0	Yampa River At Steamboat Springs
9241000	231,396	233,769	-2,373	-1	Elk River At Clark
9244410	834,379	836,454	-2,074	0	Yampa River Below Diversion near Hayden
9245000	42,324	42,324	0	0	Elkhead Creek Near Elkhead
9245500	*No gage during calibration period*			0	North Fork Elkhead Creek
9246920	7,588	7,642	-55	-1	Fortification Creek near Fortification
9247600	887,401	889,096	-1,695	0	Yampa River Below Craig
9249000	*No gage during calibration period*			0	East Fork Of Williams Fork
9249200	28,073	28,072	0	0	South Fork Of Williams Fork
9249750	154,433	154,871	-438	0	Williams Fork At Mouth
9251000	1,111,651	1,113,598	-1,948	0	Yampa River Near Maybell
9253000	163,363	163,424	-60	0	Little Snake River Near Slater
9255000	59,834	59,975	-141	0	Slater Fork Near Slater
9255500	39,077	39,077	0	0	Savery Creek at Upper Station
9256000	85,981	85,982	0	0	Savery Creek near Savery
9257000	378,895	379,173	-278	0	Little Snake River Near Dixon

Gage ID	Historical	Simulated	Historical minus Simulated		Gage Name
			Volume	Percent	
9258000	7,930	7,977	-47	-1	Willow Creek Near Dixon
9260000	396,915	397,235	-320	0	Little Snake River Near Lily
9260050	1,490,492	1,492,104	-1,612	0	Yampa River At Deerlodge Park

7.4.3 Diversion Calibration Results

Table 7.4 summarizes the average annual shortage (deviation of simulated from historical diversion) for water years 1975 through 2005, on a sub-basin basis. Table 7.6 (at the end of this section) shows the average annual shortages for water years 1975 through 2005 by structure. On a basin-wide basis, average annual diversions differ from historical diversions by 1.6 percent in the calibration run. Estimated diversions are within a few percentages of recorded diversions except in a couple areas:

- Shortages in District 58 are generally confined to tributaries in the upper Bear River, probably due to inaccurate distribution of baseflows at gage sites to ungaged locations. The model uses the same distribution factors in every simulation month, whereas, in reality, the percentage contribution of sub-basins changes from month to month.

- The Union Ditch (580914) is shorted because it currently has no water rights, according to the database. The ditch was inundated by Stagecoach Reservoir but diversions continue to be recorded, apparently to support mitigation wetlands. The issue is being researched.

- According to the model the Allen Basin Supply ditch diverts more than it did historically. In the model, the diversion is limited by available capacity in the reservoir rather than headgate demand.

- Structures in the Fortification Creek, Marapos Creek (Williams Fork tributary), and Milk Creek basins continue to exhibit significant shortages, despite adjustments made to baseflow hydrology during calibration. These adjustments, which reduced shortages relative to the initial model, are described above in Section 7.3.

Table 7.4
Historical and Simulated Average Annual Diversions by Sub-basin (1975-2005)
Calibration Run (acre-feet/year)

Tributary or Sub-basin	Historical	Simulated	Historical minus Simulated	
			Volume	Percent
Upper Yampa River (Stagecoach Reservoir gage and above)	85,979	84,596	1,383	1.6%
Yampa River (Stagecoach Reservoir to Elk River)	41,550	40,452	1,098	2.6%
Elk River	39,267	39,021	246	0.6%
Trout Creek	12,979	12,937	42	0.3%
Elkhead Creek	7,283	7,114	169	2.3%
Fortification Creek	7,888	7,187	701	8.9%
Yampa River (Elk River to Craig gage)	70,332	70,331	1	0.0%
Williams Fork	33,036	31,699	1,337	4.0%
Yampa River (Williams Fork to Little Snake River)	62,419	62,324	95	0.2%
Upper Little Snake River (above Muddy Creek)	100,372	98,972	1,400	1.4%
Lower Little Snake River (Muddy Creek and below)	65,395	63,021	2,374	3.6%
Yampa River below Little Snake River	13,687	13,687	0	0.0%

7.4.4 Reservoir Calibration Results

Figures 7.8 through 7.11 (located at the end of this chapter) present reservoir EOM contents estimated by the model compared to historical observations at selected reservoirs. The following can be observed:

- Yamcolo Reservoir is greatly underused in the calibration run. Although the Stillwater Reservoir hydrograph is not included in the figures, the same is true for Stillwater. With the exception of the Stillwater Ditch, the Yamcolo and Stillwater users are not shorted, so they appear to get their supply from direct flow. The discrepancies may be due to an incorrect distribution of baseflow to ungaged points. Or perhaps in the real world, irrigators begin to use storage water before they absolutely have to, leaving more water in the stream for junior diverters like Stagecoach Reservoir.

- Stagecoach Reservoir tends to show lower than historical levels in the peak months, by several hundred acre-feet. This is partly due to the fact that reported contents are a little higher than the stated maximum operating capacity for the reservoir. It also reflects the way that StateMod handles evaporation. After all storing and releasing operations are finished for the time step, StateMod computes the evaporated volume and subtracts that from reservoir contents. Thus simulated end-of-month contents can never reach maximum capacity for the reservoir, even when supply exceeds storage capacity.

- Neither Steamboat Lake nor Elkhead Reservoir sees much use. The Division 6 office described these lakes as generally being kept full, although they have historically made releases from time to time. There are no operating rules in the model to release from the conservation pool in Steamboat Lake. Some of the historical releases from the lake, especially from 1997 to 2002, are known to have been made for instream flow protection. However, the operation was conducted under a five-year lease that is currently being renegotiated. The operation may be added to the model in the future if arrangements for its perpetuation are formalized by the participating entities.

- Colorado Department of Parks provided the active capacity of Steamboat Lake. The value used in the model, 26,364 af, includes 3,300 af controlled by spillway gates. From the Calculated simulation hydrograph, it appears that Steamboat Lake is not normally operated with the spillway gates closed.

7.5.5 Irrigation Consumptive Use Calibration Results

Table 7.5 compares StateCU-estimated crop consumptive use with StateMod estimate of crop consumptive use for explicit structures, aggregate structures, and basin total (exclusive of Wyoming, where lack of ditch specific irrigated lands, diversion records, and crops preclude a reliable StateCU estimate). Consumptive use attributable to municipal, industrial, or transbasin diversions is also not included. As shown, both explicit and aggregate structure consumptive use are less than StateCU results, but within 2 percent. Historical diversions are used by StateCU to estimate supply-limited (actual) consumptive use.

Table 7.5
Average Annual Crop Consumptive Use Comparison (1975-2005)

Comparison	StateCU Results (af/yr)	Calibration Run Results (af/yr)	% Difference
Explicit Structures	82,073	80,052	2.5
Aggregate Structures	57,121	57,075	0.1
Basin Total (within Colorado)	139,194	137,127	1.5

Table 7.6
Historical and Simulated Average Annual Diversions (1975-2005)
Calibration Run (acre-feet/year)

WD ID	Historical	Simulated	Historical minus Simulated Volume	Historical minus Simulated Percent	Structure Name
440509	975	975	0	0	WILSON DITCH
440511	2,520	2,514	6	0	WISCONSIN DITCH
440514	487	487	0	0	WOOLEY & JOHNSON D
440517	1,036	1,036	0	0	YAMPA VAL STOCK BR CO D
440518	287	247	40	14	YELLOW JACKET DITCH NO 1
440522	11,577	11,577	0	0	CRAIG STATION D & PL #1
440524	184	184	0	0	A Q DITCH 1
440527	269	269	0	0	AIR LINE IRR D
440533	207	171	36	17	ANDERSON DITCH
440541	799	799	0	0	BAILEY DITCH
440570	1,221	1,221	0	0	CARD DITCH
440572	106	89	17	16	CARRIGAN-AVERILL D
440573	767	637	130	17	CATARACT DITCH
440581	1,758	1,758	0	0	CRAIG WATER SUPPLY PL
440583	3,012	3,012	0	0	CROSS MTN PUMP - GROUNDS
440584	2,661	2,661	0	0	CROSS MTN PUMP NO 1
440585	378	378	0	0	CRYSTAL CK DITCH
440586	2,139	2,139	0	0	D D & E DITCH
440587	1,425	1,425	0	0	D D FERGUSON D NO 2
440589	5,911	5,911	0	0	DEEP CUT IRR D
440590	1,347	1,217	130	10	DEER CK & MORAPOS D
440593	334	304	30	9	DENNISON & MARTIN D
440601	717	717	0	0	DUNSTON DITCH
440607	3,444	3,327	117	3	EGRY MESA DITCH
440611	888	296	592	67	ELK TRAIL DITCH
440612	683	529	154	23	ELKHORN IRR DITCH
440613	257	257	0	0	ELLGEN DITCH
440614	275	236	39	14	ELLIS & KITCHENS D
440628	334	291	43	13	GIBBONS WILSON JORDAN D
440635	415	415	0	0	GRIESER DITCH
440638	294	207	88	30	HADDEN BASE DITCH

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
440644	253	253	0	0	HARPER DITCH 1
440645	196	194	2	1	HARPER DITCH 2
440647	708	649	59	8	HAUGHEY IRR DITCH
440650	22	22	0	0	HIGHLINE MESA BAKER D
440651	1,642	1,577	64	4	HIGHLAND DITCH
440652	855	855	0	0	HIGHLAND AKA HIGHLINE D
440660	394	394	0	0	J A MARTIN DITCH
440661	498	497	1	0	J P MORIN DITCH
440675	3,554	3,554	0	0	JUNIPER MTN TUNNEL
440677	1,813	1,813	0	0	K DIAMOND DITCH
440681	297	269	27	9	LAMB IRR DITCH
440687	2,451	2,451	0	0	LILY PARK D PUMP STA NO
440688	1,558	1,334	224	14	LITTLE BEAR DITCH
440691	1,075	1,075	0	0	M DITCH
440692	2,134	2,079	55	3	MARTIN CK DITCH
440694	16,032	16,032	0	0	MAYBELL CANAL
440695	95	95	0	0	MAYBELL MILL PIPELINE
440698	310	287	24	8	MCDONALD DITCH
440699	745	729	16	2	MCKINLAY DITCH NO 1
440700	1,329	1,296	34	3	MCKINLAY DITCH NO 2
440702	1,938	1,938	0	0	MCINTYRE DITCH
440706	570	570	0	0	MILK CK DITCH
440711	861	861	0	0	MOCK DITCH
440716	126	126	0	0	MULLEN DITCH
440723	925	925	0	0	NICHOLS DITCH NO 1
440724	1,805	1,779	26	1	NORVELL DITCH
440729	1,932	1,932	0	0	PATRICK SWEENEY D
440731	1,256	1,256	0	0	PECK IRRIG D
440735	625	542	83	13	PINE CK DITCH
440740	641	641	0	0	RATCLIFF DITCH
440747	183	141	43	23	ROBY D AKA ROBY D NO 1
440748	152	116	36	24	ROBY DITCH NO 2
440749	100	100	0	0	ROUND BOTTOM D NO 1
440750	245	245	0	0	ROUND BOTTOM D NO 2
440751	131	131	0	0	ROUND BOTTOM DITCH

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
440763	1,122	1,115	8	1	SMITH DITCH
440770	222	218	4	2	STARR IRRIG DITCH
440778	1,581	1,581	0	0	SUNBEAM DITCH
440785	686	630	56	8	TIPTON IRR DITCH
440786	1,685	1,685	0	0	TISDEL D NO 2
440790	1,152	1,152	0	0	UTLEY DITCH
440801	1,236	1,236	0	0	CROSS MTN PUMP - GUESS
440806	219	219	0	0	ELLGEN NO 2 DITCH
440812	238	148	90	38	HART DITCH
440814	514	512	1	0	HIGHLINE DITCH
440820	1245	1245	0	0	LOWRY SEELEY PUMP
440821	283	283	0	0	MACK DITCH
440830	1393	1393	0	0	OLD SWEENEY DITCH
440863	1554	1554	0	0	HENRY SWEENEY DITCH
440998	337	316	22	6	DRY COTTONWOOD DITCH 1
441122	1766	1766	0	0	VAUGHN PUMP
442214	205	205	0	0	WISE DITCH ALT PT
44_ADY012	1,578	1,570	8	1	Elkhead Creek
44_ADY013	3,858	3,858	0	0	Yampa River bl Craig
44_ADY014	5,678	5,678	0	0	East Fork Williams Fork
44_ADY015	3,737	3,737	0	0	South Fork Williams Fork
44_ADY016	5,812	5,812	0	0	Williams Fork
44_ADY017	799	799	0	0	Milk Creek above G Sprin
44_ADY018	2,251	2,251	0	0	Milk Creek
44_ADY019	3,571	3,571	0	0	Yampa River near Maybell
44_ADY025	4,342	4,342	0	0	Yampa River at Deerlodge
44_AMY001	742	742	0	0	44_AMY001_YampaRbelCraig
44_FDP001	0	0	0	0	44_FDP_WD_44
44_WSA	0	0	0	0	44_WSA_EDFdemand
540507	1,122	1,101	21	2	BEELER DITCH
540531	2,302	2,181	122	5	HEELEY DITCH
540532	1,214	1,199	15	1	HOME SUPPLY DITCH
540543	940	886	53	6	LUCHINGER DITCH
540548	1,345	1,345	0	0	MORGAN & BEELER D
540549	709	699	10	1	MORGAN SLATER DITCH

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
540554	366	301	65	18	PERKINS FOX DITCH
540555	967	945	23	2	PERKINS IRR DITCH
540564	594	580	14	2	SALISBURY DITCH
540568	753	752	0	0	SLATER FORK DITCH
540570	577	521	56	10	SLATER PARK DITCH NO 1
540571	301	256	45	15	SLATER PARK DITCH NO 2
540574	881	635	246	28	Slater Park Ditch DivSys
540583	4,593	4,581	12	0	TROWEL DITCH
540591	2,060	1,829	230	11	WILLOW CK DITCH
540592	348	330	18	5	WILSON DITCH
540594	610	610	0	0	WOODBURY DITCH
54_ADY020	6,519	6,463	56	1	Little Snake river near
54_ADY021	5,221	5,215	6	0	Little Snake River above
54_ADY022	7,074	7,005	68	1	Slater Creek
54_ADY023	37,376	35,138	2238	6	Little Snake above Dry G
550504	884	884	0	0	ESCALANTA PUMP 2
550506	2,000	2,000	0	0	MAJORS PUMP NO 2
550507	928	928	0	0	NINE MILE IRR DITCH
550508	767	767	0	0	NINE MILE IRR PL
550513	693	693	0	0	VISINTAINER DITCH
550519	704	704	0	0	RINKER PUMP D
550537	1,459	1,459	0	0	LEFEVRE NO 1 PUMP
55_ADY024	4,567	4,567	0	0	Little Snake river near
55_ADY026	674	674	0	0	Yampa River at Green Riv
55_AMY003	13	13	0	0	55_AMY003_LSnakeRnrLily
55_FDP001	0	0	0	0	Fu_Dev_55
56_ADY027	8,671	8,671	0	0	Green River
56_FDP001	0	0	0	0	Fu_Dev_56
570508	2,564	2,564	0	0	BROCK DITCH
570510	3,581	3,581	0	0	CARY DITCH CO DITCH
570512	4,481	4,481	0	0	COLO UTILITIES D & PL
570517	680	680	0	0	DAVID M CHAPMAN DITCH
570519	893	893	0	0	DENNIS & BLEWITT D
570524	447	441	6	1	EAST SIDE DITCH
570525	550	550	0	0	EAST SIDE DITCH 2

WD ID	Historical	Simulated	Historical minus Simulated Volume	Percent	Structure Name
570535	432	432	0	0	ERWIN IRRIGATING DITCH
570539	6,668	6,668	0	0	GIBRALTAR DITCH
570544	911	911	0	0	HIGHLAND DITCH
570545	970	970	0	0	HOMESTEAD DITCH
570555	922	920	2	0	LAST CHANCE DITCH
570561	471	463	8	2	MALE MOORE CO DITCH
570563	3,775	3,775	0	0	MARSHALL ROBERTS DITCH
570576	486	486	0	0	ORNO DITCH
570579	810	810	0	0	R E CLARK DITCH
570584	589	589	0	0	SADDLE MOUNTAIN DITCH
570592	7,116	7,116	0	0	SHELTON DITCH
570608	856	856	0	0	TROUT CREEK DITCH 3
570609	276	273	3	1	TROUT CREEK DITCH 2
570611	5,394	5,394	0	0	WALKER IRRIG DITCH
570622	2,618	2,617	0	0	WILLIAMS IRRIG DITCH
570623	639	639	0	0	WILLIAMS PARK DITCH
570635	1,011	1,011	0	0	KOLL DITCH
574629	1,469	1,459	10	1	RICH DITCH
57_ADY009	3,291	3,278	13	0	Trout Creek
57_ADY010	1,761	1,761	0	0	Yampa River near Hayden
57_ADY011	2,170	2,170	0	0	Yampa River above Elkhea
57_AMY001	484	484	0	0	57_AMY001_YampaRabCraig
57_FDP001	0	0	0	0	Fu_Dev_57
57_NAG01	0	0	0	0	Nu_Ag_Dev
57_NMID01	0	0	0	0	Nu_Fu_M&I
57_NPWR01	0	0	0	0	Nu_Fu_Pwr
580500	1,527	1,527	0	0	ACTON D
580506	187	227	-40	-22	ALLEN BASIN SUPPLY D
580508	1,048	1,040	9	1	ALPHA DITCH
580530	2,067	2,067	0	0	BAXTER DITCH
580532	286	285	1	0	BEAVER CREEK D
580539	4,157	4,044	114	3	BIG MESA DITCH
580541	1,638	1,638	0	0	BIRD DITCH
580556	307	278	29	9	BRINKER CREEK DITCH
580559	591	591	0	0	BROOKS DITCH

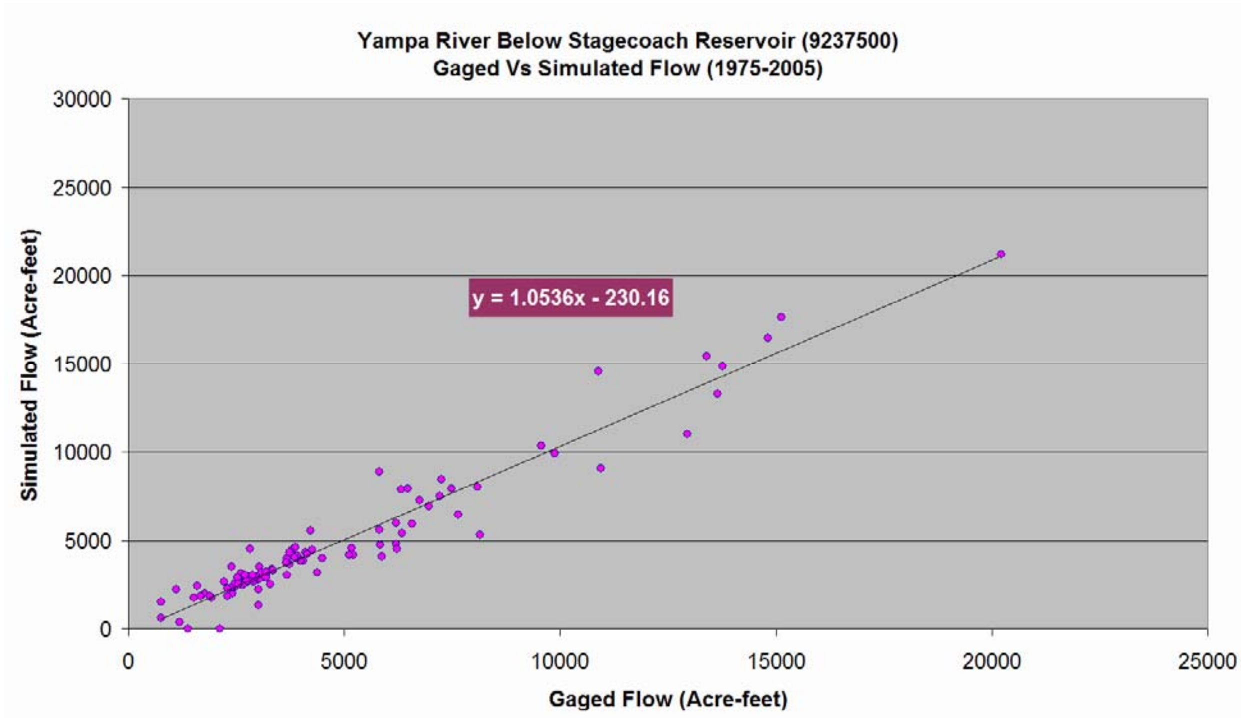
WD ID	Historical	Simulated	Historical minus Simulated Volume	Historical minus Simulated Percent	Structure Name
580561	315	315	0	0	BRUMBACK DITCH
580564	2,325	2,325	0	0	BUCKINGHAM MANDALL D
580568	1,307	1,307	0	0	BURNETT DITCH
580569	249	248	1	0	BURNT MESA D
580574	245	243	2	1	C R BROWN MOFFAT COAL D
580577	1,088	1,088	0	0	CAMPBELL DITCH
580582	433	422	11	3	CHARLES & A LEIGHTON D
580583	238	238	0	0	CHARLES H KEMMER D
580588	679	676	4	1	CLARK & BURKE DITCH
580590	129	129	0	0	COLEMAN DITCH
580591	760	760	0	0	COLLINS DITCH
580599	686	686	0	0	CULLEN DITCH 2
580604	144	144	0	0	DAY DITCH
580612	468	468	0	0	DEVER D
580618	1,691	1,691	0	0	DUQUETTE DITCH
580622	1,578	1,578	0	0	EGERIA DITCH
580623	1,044	1,043	0	0	EKHART DITCH
580626	2,655	2,646	9	0	ELK VALLEY DITCH CO. D.
580627	2,284	2,041	243	11	ENTERPRISE DITCH
580628	301	301	0	0	EXCELSIOR DITCH
580633	1,200	1,161	39	3	FELIX BORGHI DITCH
580634	901	862	39	4	FERGUSON DITCH
580640	395	394	1	0	FIRST CHANCE DITCH
580642	2,138	2,092	47	2	FISH CR MUN WATER INTAKE
580643	1,489	1,489	0	0	FIX DITCH
580649	1,788	1,787	1	0	FRANZ DITCH
580662	1,946	1,945	1	0	GRAHAM & BENNETT D
580663	500	472	28	6	GREER DITCH
580665	188	188	0	0	GUIDO DITCH
580684	943	943	0	0	HERNAGE & KOLBE DITCH
580685	349	349	0	0	HIGH MESA IRR D
580687	368	354	15	4	HIGHLINE BEAVER DITCH
580694	2,061	2,042	19	1	HOOVER JACQUES DITCH
580695	711	708	4	1	HOT SPGS CR HIGHLINE D
580714	2,201	2,200	0	0	KELLER DITCH

WD ID	Historical	Simulated	Historical minus Simulated Volume	Historical minus Simulated Percent	Structure Name
580717	1,129	1,091	38	3	KINNEY DITCH
580721	482	477	5	1	L L WILSON D
580722	388	388	0	0	LAFON DITCH
580728	573	568	5	1	LARSON DITCH
580730	594	618	-24	-4	LATERAL A DITCH
580731	255	255	0	0	LAUGHLIN DITCH
580738	1,201	1,201	0	0	LINDSEY DITCH
580749	396	396	0	0	LOWER PLEASANT VALLEY D
580756	398	398	0	0	LYON DITCH 2
580763	4,321	4,321	0	0	MANDALL DITCH
580767	354	354	0	0	MAYFLOWER DITCH
580777	443	443	0	0	MILL DITCH 1
580782	229	214	15	6	MOODY DITCH
580783	2,850	2,816	34	1	MORIN DITCH
580798	922	922	0	0	NICKELL DITCH
580801	298	298	0	0	NORTH HUNT CREEK DITCH
580805	717	717	0	0	OAK CREEK DITCH
580807	528	527	2	0	OAK DALE DITCH
580808	1,022	1,014	8	1	OAKTON DITCH
580809	196	196	1	0	OLD CABIN DITCH
580811	235	235	0	0	OLIGARCHY DITCH
580813	437	434	3	1	PALISADE DITCH
580821	1,489	1,489	0	0	PENNSYLVANIA DITCH
580826	267	203	65	24	PONY CREEK D
580830	178	163	15	8	PRIEST DITCH
580844	358	358	0	0	SAGE HEN DITCH
580847	288	288	0	0	SAND CREEK DITCH
580863	1,733	1,733	0	0	SIMON DITCH
580866	701	689	12	2	SNOW BANK DITCH
580868	1,899	1,818	81	4	SODA CREEK DITCH
580872	595	593	2	0	SOUTH SIDE DITCH
580879	2,482	2,389	93	4	STAFFORD DITCH
580895	971	958	12	1	SUNNYSIDE DITCH 1
580897	2,396	2,396	0	0	SUTTLE DITCH
580908	437	437	0	0	TRULL MORIN DITCH

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
580914	1,517	610	908	60	UNION DITCH
580915	948	924	24	3	UPPER ELK RIVER D CO. D
580916	1,120	1,120	0	0	UPPER PLEASANT VALLEY D
580917	428	425	3	1	VAIL SAVAGE DITCH
580920	9,882	9,266	616	6	WALTON CREEK DITCH
580922	551	551	0	0	WEISKOPF DITCH
580924	201	200	1	1	WELCH & MONSON D
580928	432	427	5	1	WHEELER BROS DITCH
580933	548	548	0	0	WHIPPLE DITCH
580939	351	351	0	0	WINDSOR DITCH
580943	230	195	35	15	WOODCHUCK D SODA CK HG
580944	2,079	2,079	0	0	WOOLERY DITCH
580945	1,164	1,164	0	0	WOOLEY DITCH
580980	459	429	31	7	GABIOUD DITCH
581021	866	859	7	1	LEE IRRIGATION D
581035	534	524	10	2	NORTH SIDE DITCH
581074	454	449	5	1	ROSSI HIGHLINE DITCH
581085	472	471	1	0	MILL CREEK DITCH
581583	24,493	24,489	4	0	STAGECOACH HYDROELECTRIC
582374	212	212	0	0	STEAMBOAT SKI SNOW PL
584630	255	201	54	21	Dome_Creek_Ditch
584684	617	615	2	0	SARVIS DITCH
584685	4,232	4,230	2	0	STILLWATER DITCH
584686	1,526	1,516	10	1	Stillwater_Colo
58_ADY001	3,758	3,758	0	0	Upper Bear River
58_ADY002	3,370	3,323	47	1	Chimney Creek
58_ADY003	4,612	4,600	12	0	Bear River above Hunt Cr
58_ADY004	3,455	3,452	3	0	Bear River above Stageco
58_ADY005	5,983	5,983	0	0	Yampa River above Steamb
58_ADY006	1,970	1,959	11	1	Elk River near Clark
58_ADY007	3,599	3,599	0	0	Middle Elk River
58_ADY008	5,769	5,769	0	0	Lower Elk River
58_AMY001	1,342	1,342	0	0	58_AMY001_AMY001_Yampa@S
58_FDP001	0	0	0	0	Fu_Dev_58
990528	10,190	10,190	0	0	Cheyenne_City

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
990538	0	0	0	0	New_Wyo_Ag
990539	15,446	15,446	0	0	WY_First_Mesa_Canal
990540	22,785	22,635	150	1	WY_Westside_Canal
990528	10,190	10,190	0	0	Cheyenne_City
WYD_001	1,128	1,128	0	0	WY_Divs_blw_Slater_Creek
WYD_002	664	664	0	0	WY_Divs_abv_High_Savery
WYD_003	1,294	1,286	8	1	WY_Divs_blw_High_Savery
WYD_004	1,379	1,379	1	0	WY_Divs_btwn_gages_Svery
WYD_005	5,657	5,438	219	4	WY_Divs_lower_SaveryCrk
WYD_006	1,232	1,232	0	0	WY_Divs_blw_SaveryCreek
WYD_007	9,491	9,397	93	1	WY_Divs_blw_WillowCreek
WYD_008	115	115	0	0	WY_Baggs&Dixon
WYD_009	2,548	2,548	0	0	WY_Divs_Muddy_Creek
WYD_010	1,450	1,449	1	0	WY_Divs_blw_Muddy_Creek
WYD_011	4,501	4,499	2	0	WY_Divs_abv_StateLine
Basin Total	540,190	531,334[1]	8857	2	

[1]Sum of diversions equivalent to that shown in Table 7.2 when adjustments are made for carrier ditches and reservoir feeders



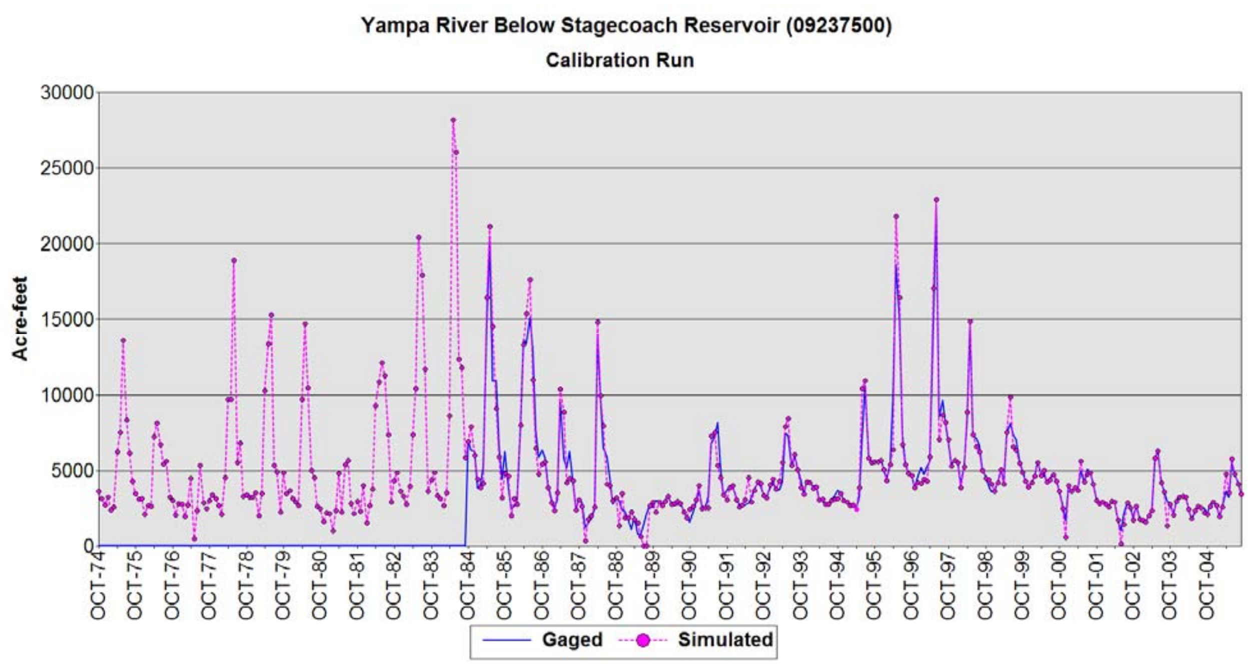
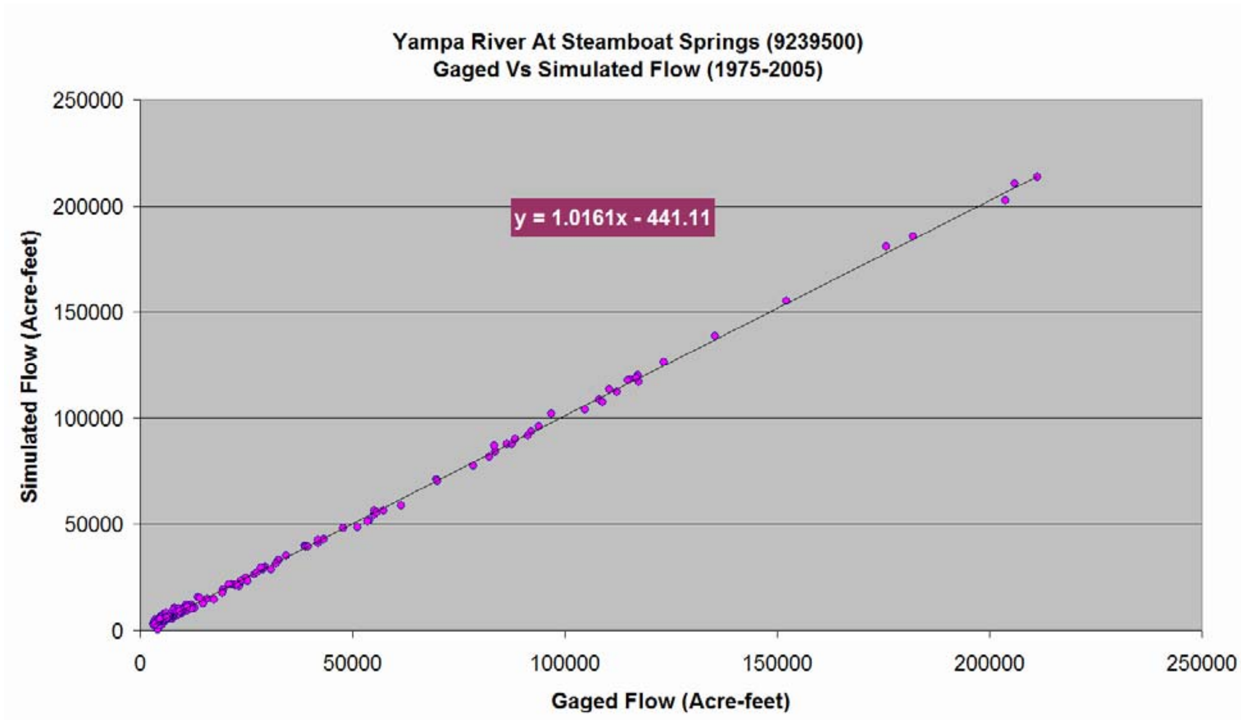


Figure 7.1 Streamflow Calibration – Yampa River below Stagecoach Reservoir



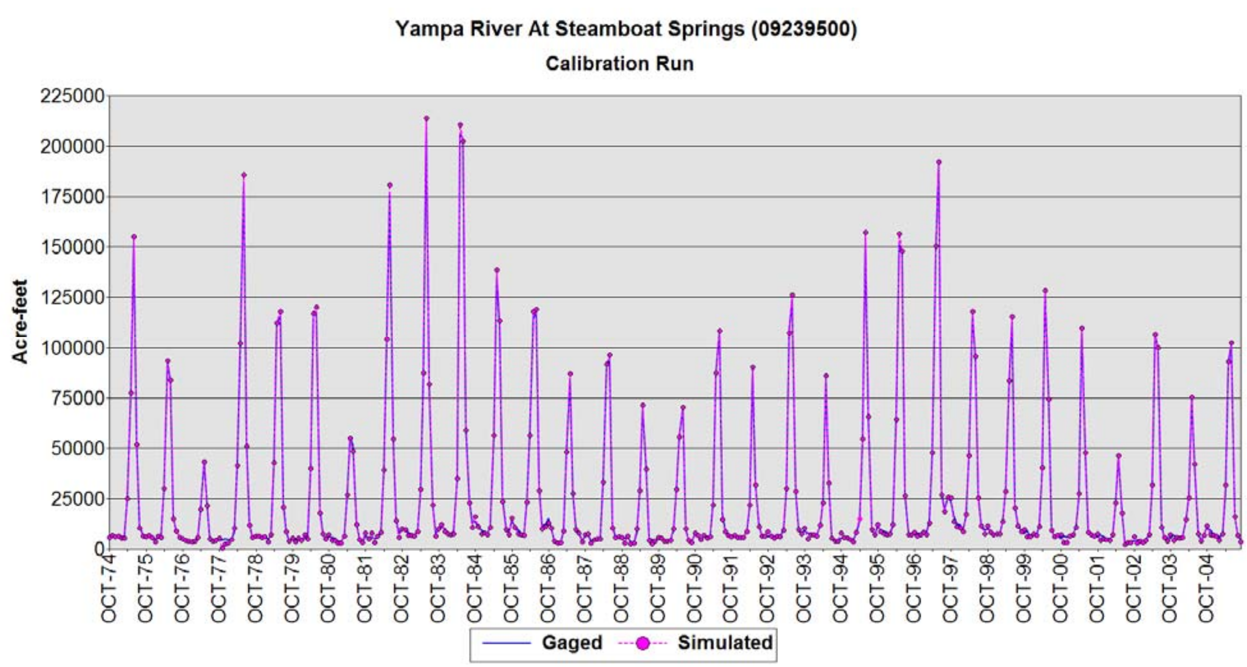
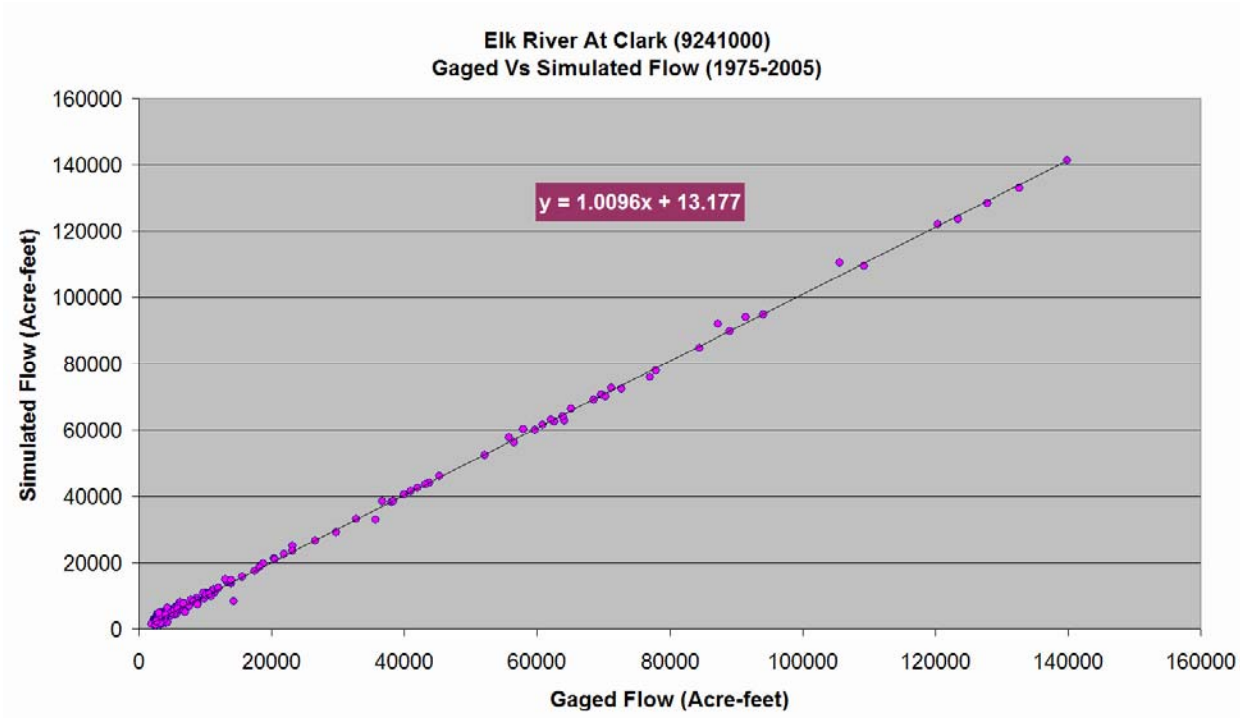


Figure 7.2 Streamflow Calibration – Yampa River at Steamboat Springs



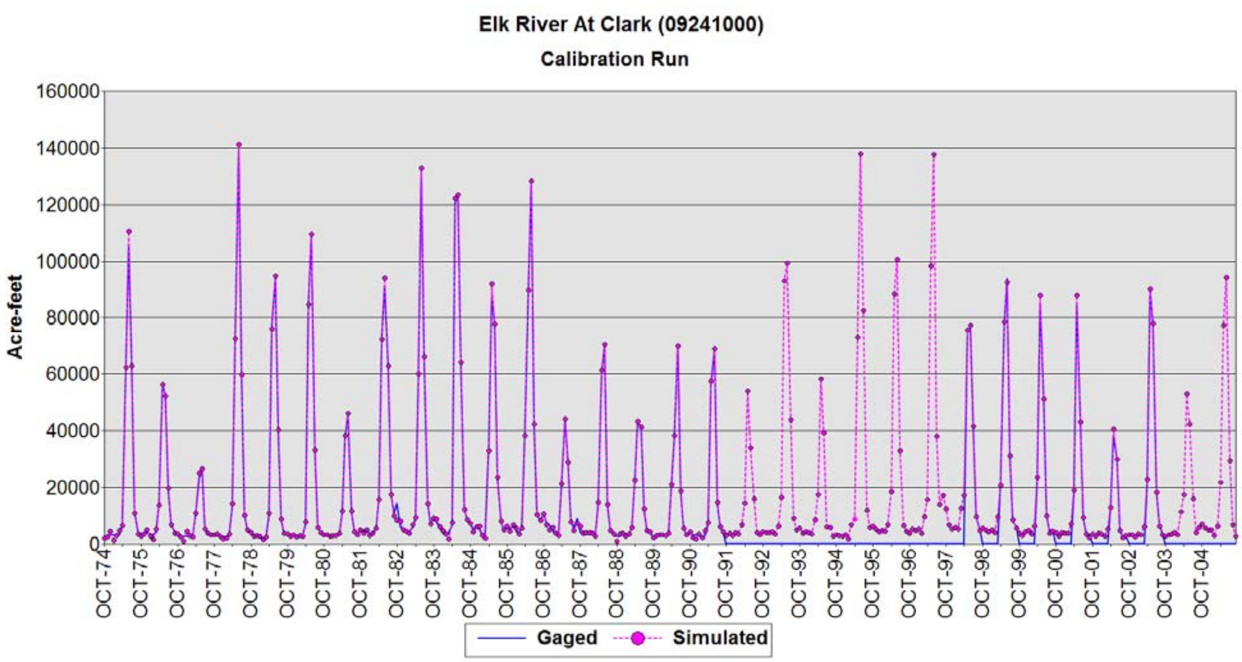
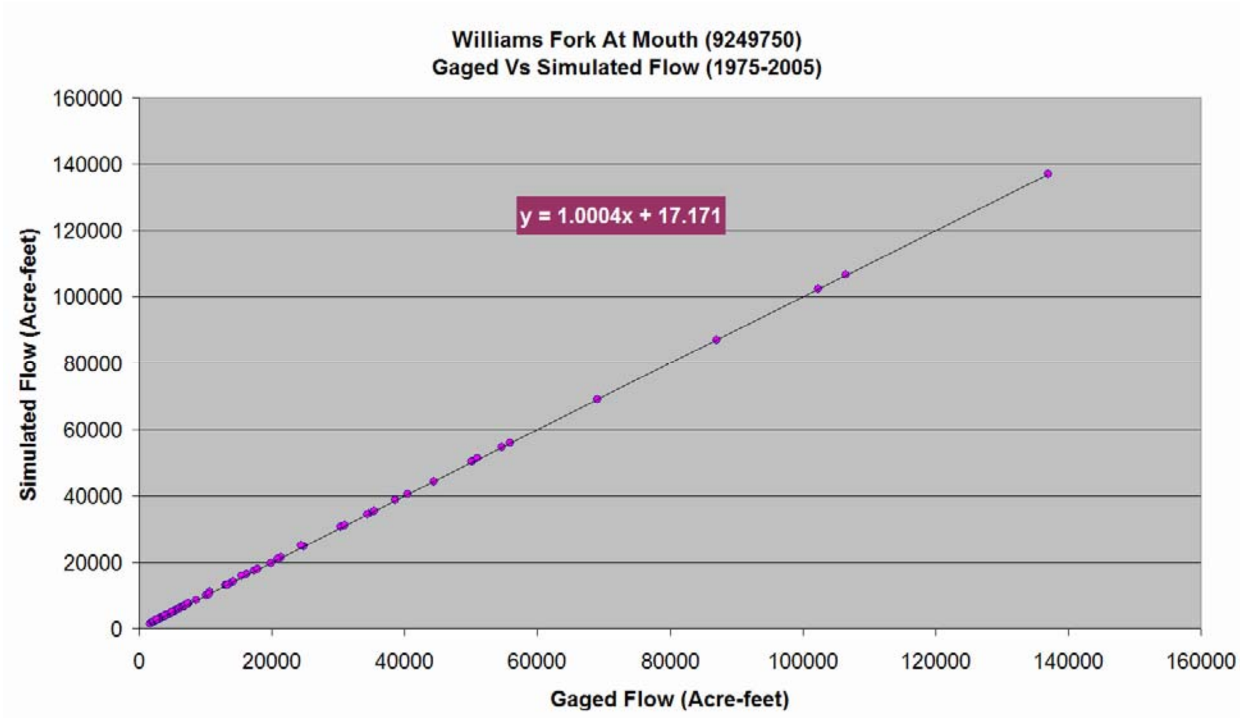


Figure 7.3 Streamflow Calibration – Elk River at Clark



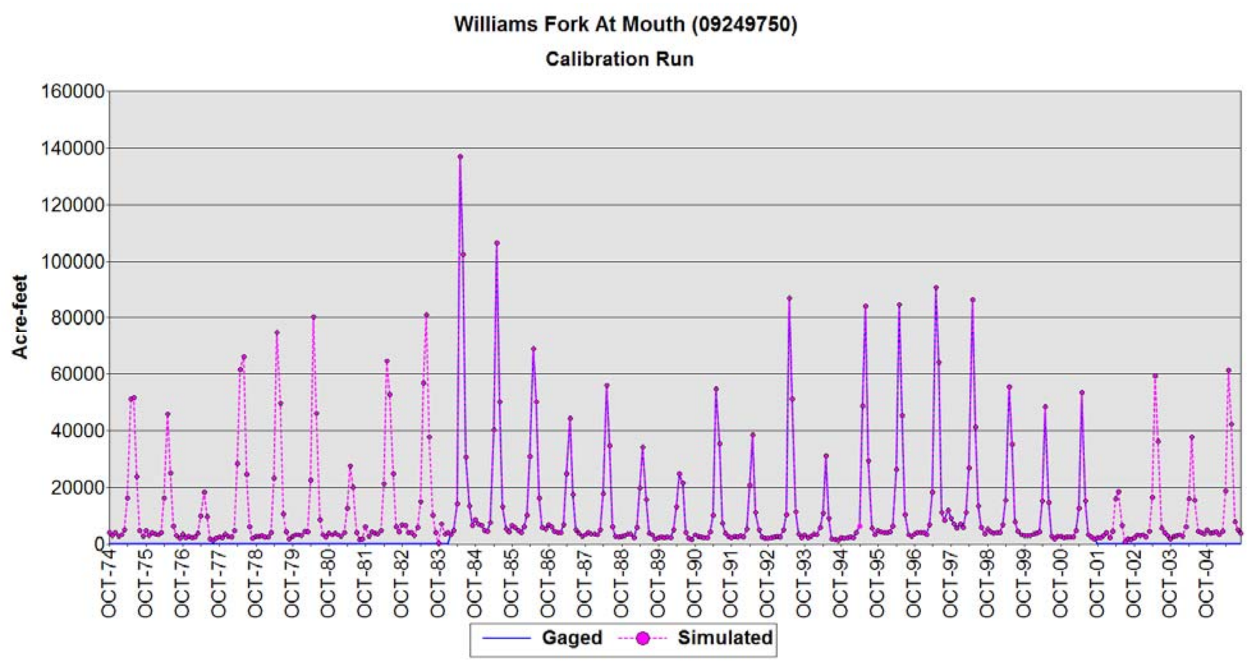
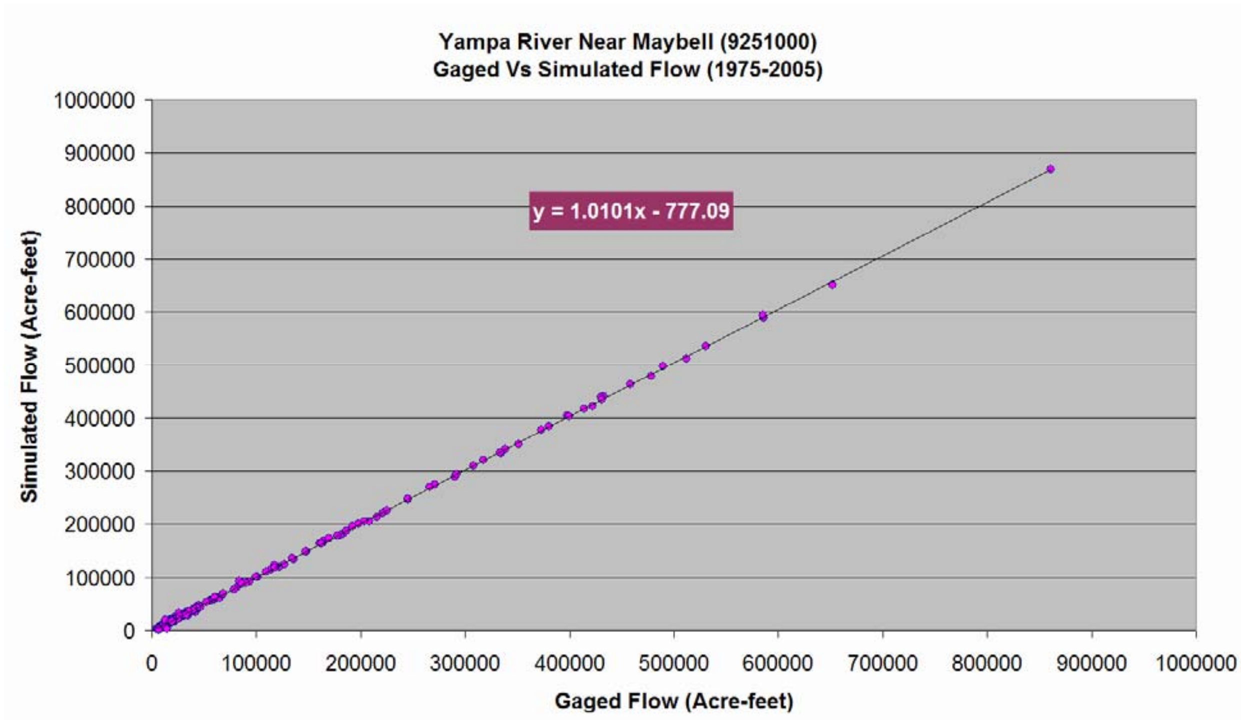


Figure 7.4 Streamflow Calibration – Williams Fork at Mouth



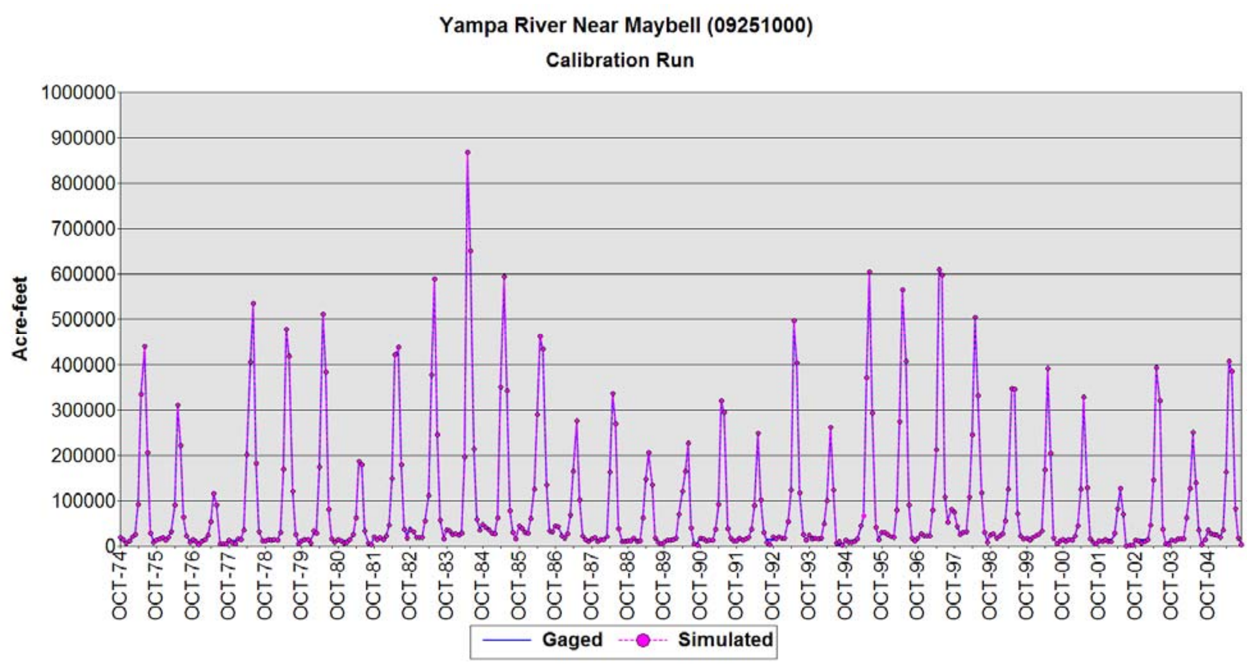
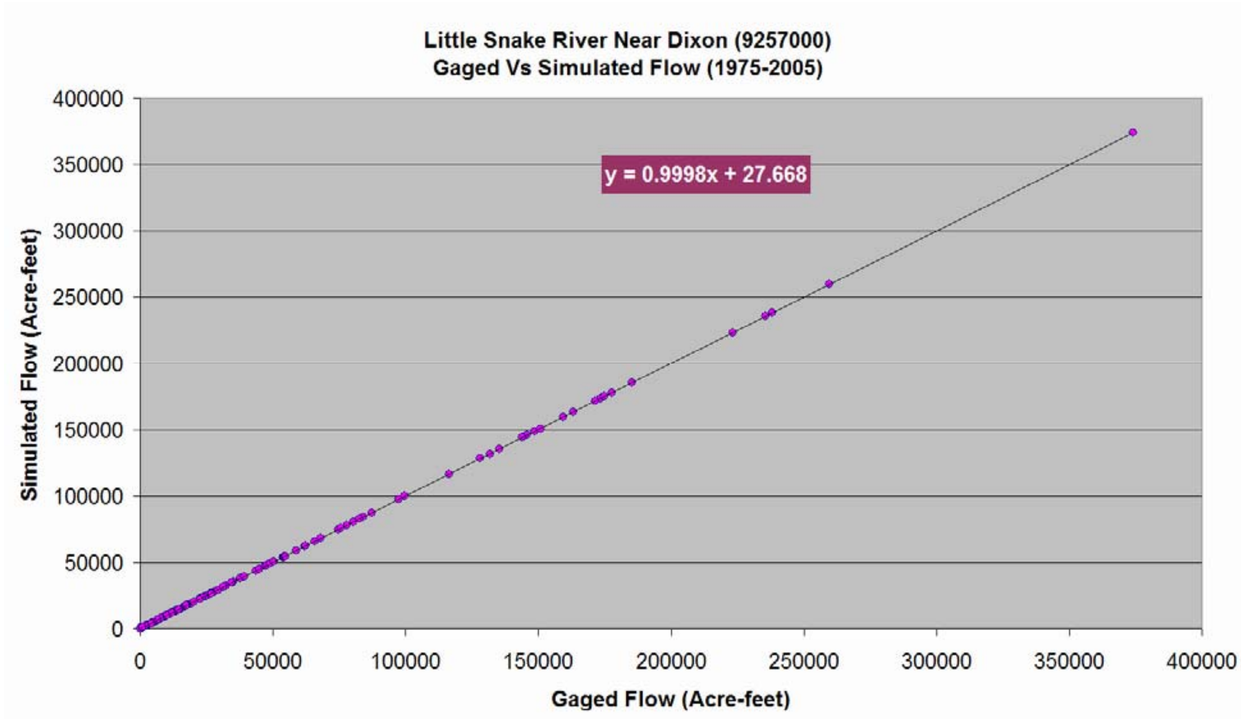


Figure 7.5 Streamflow Calibration – Yampa River near Maybell



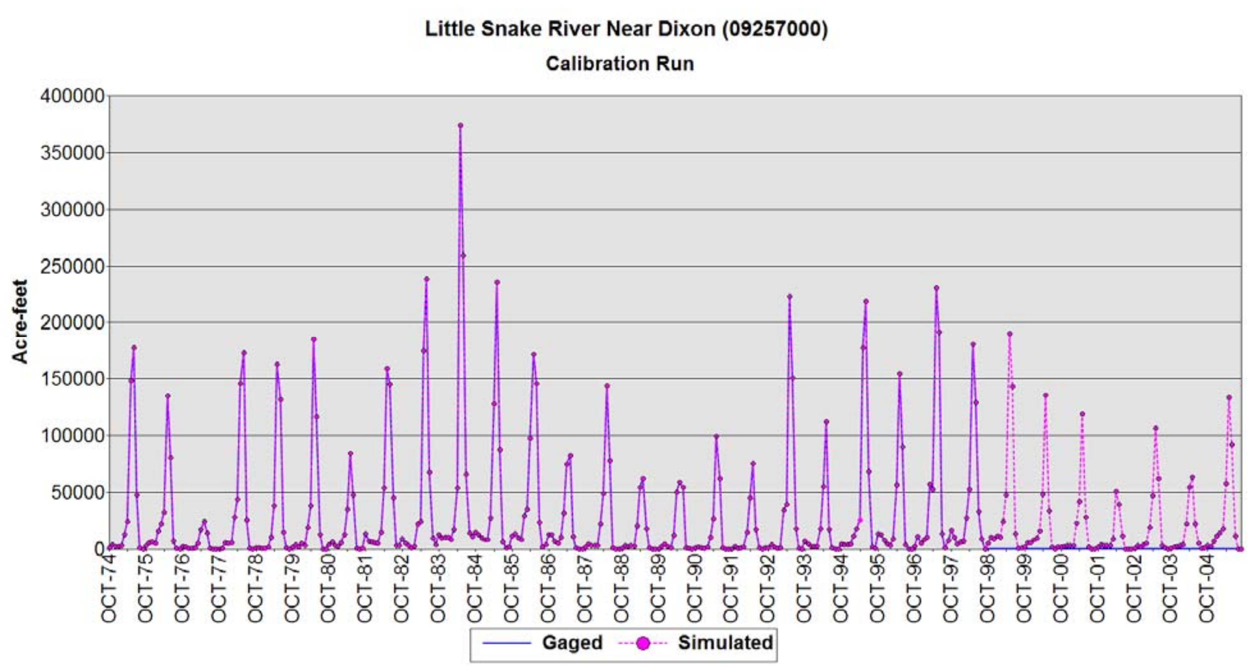
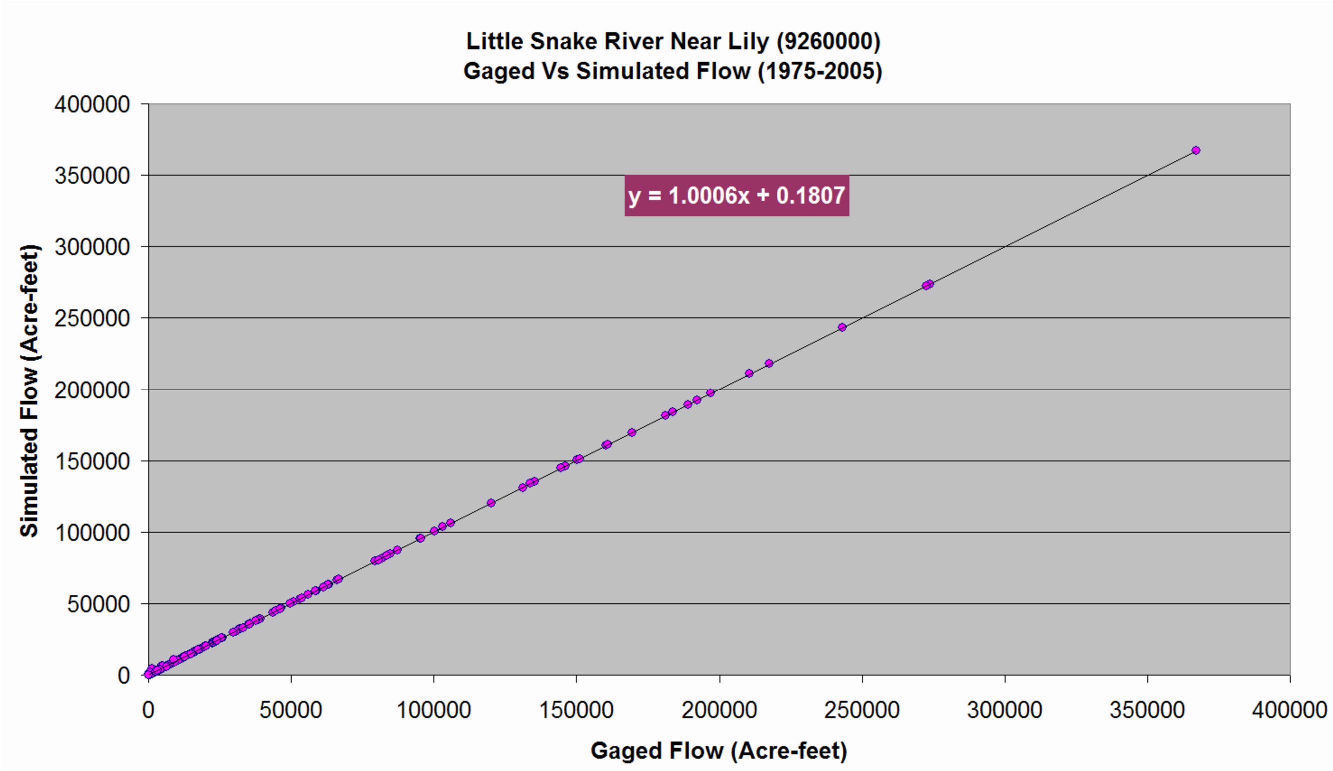


Figure 7.6 Streamflow Calibration - Little Snake near Dixon



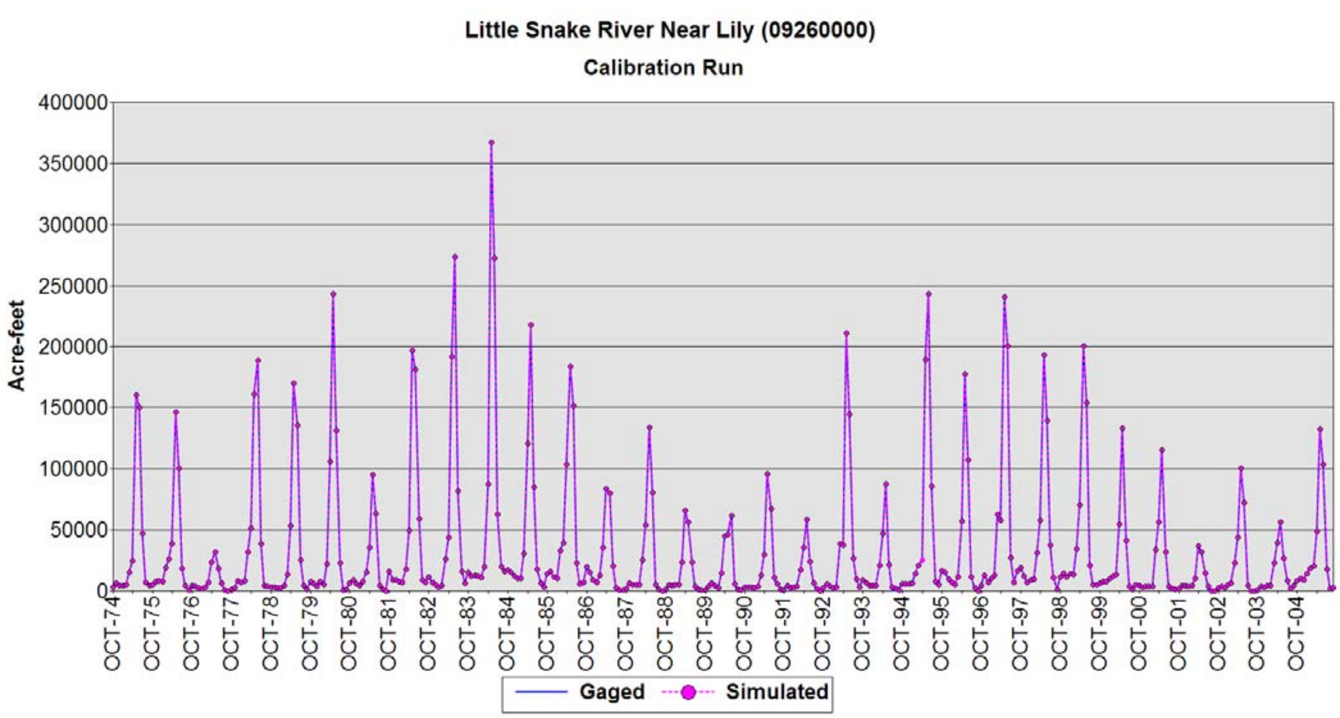


Figure 7.7 Streamflow Calibration - Little Snake River near Lily

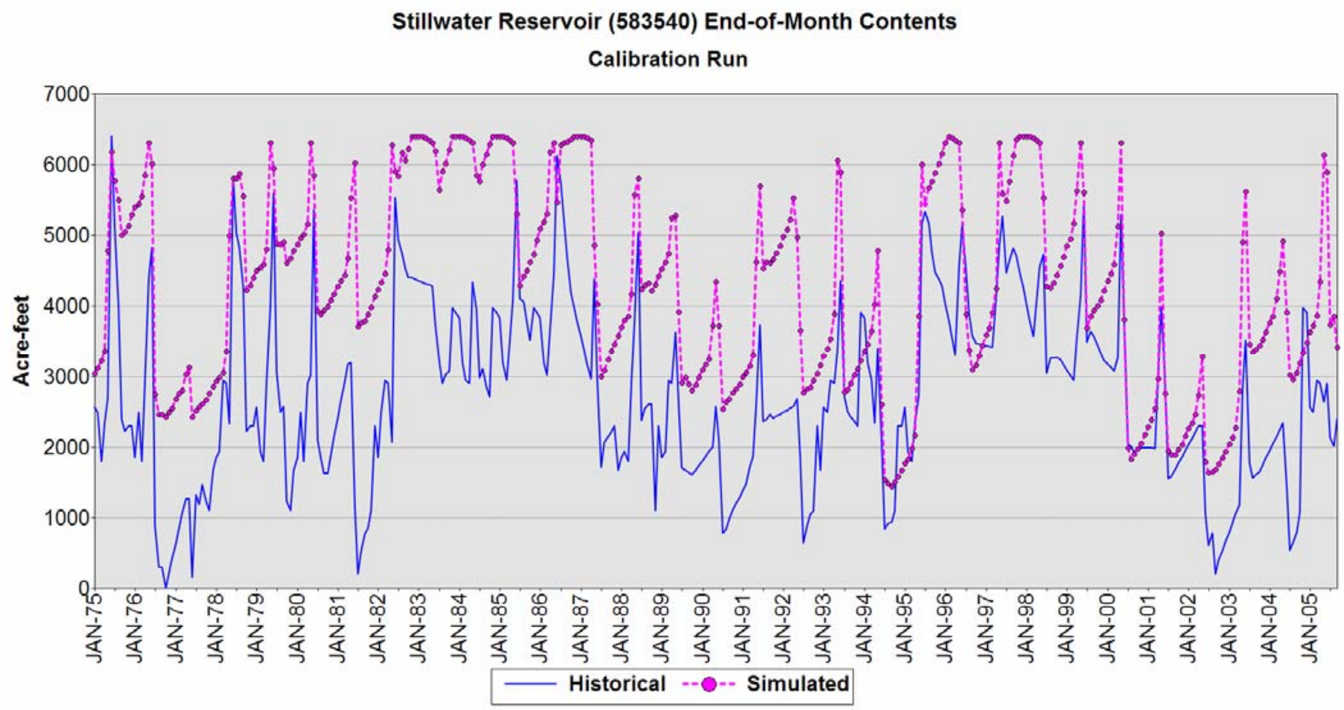


Figure 7.8 Reservoir Calibration – Stillwater Reservoir

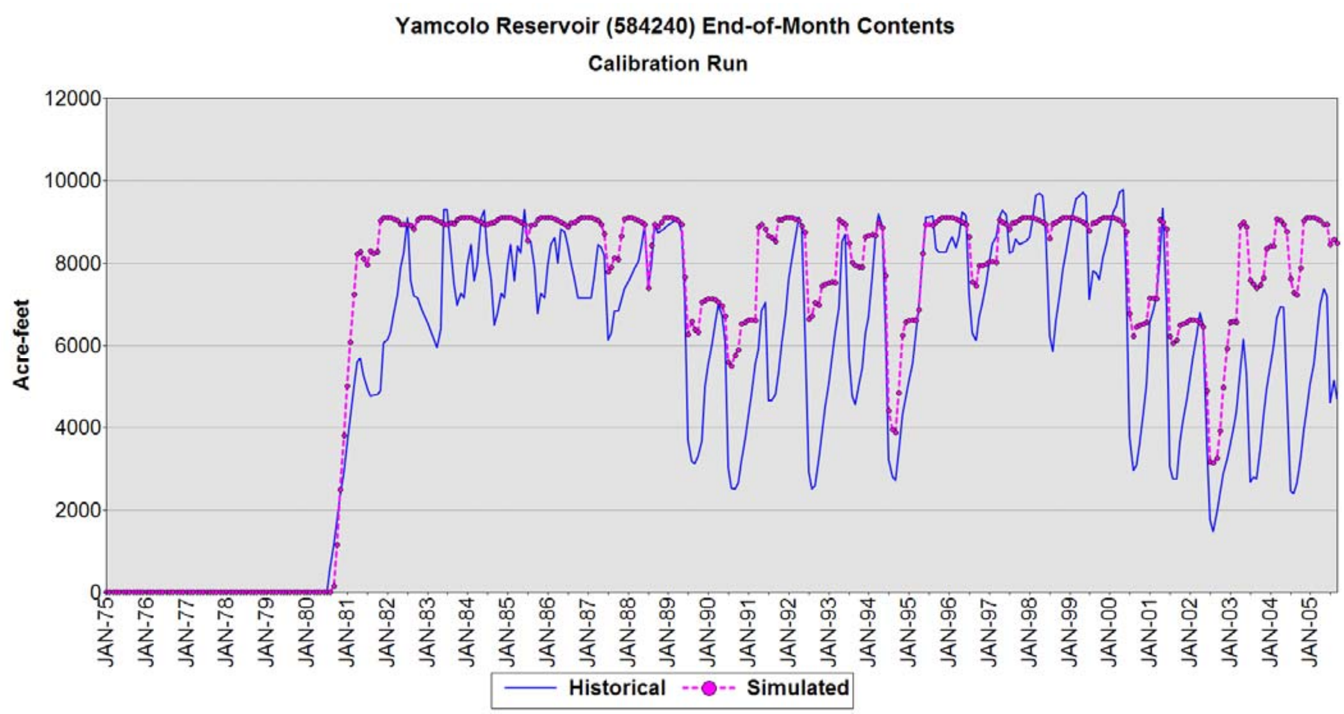


Figure 7.9 Reservoir Calibration – Yamcolo Reservoir

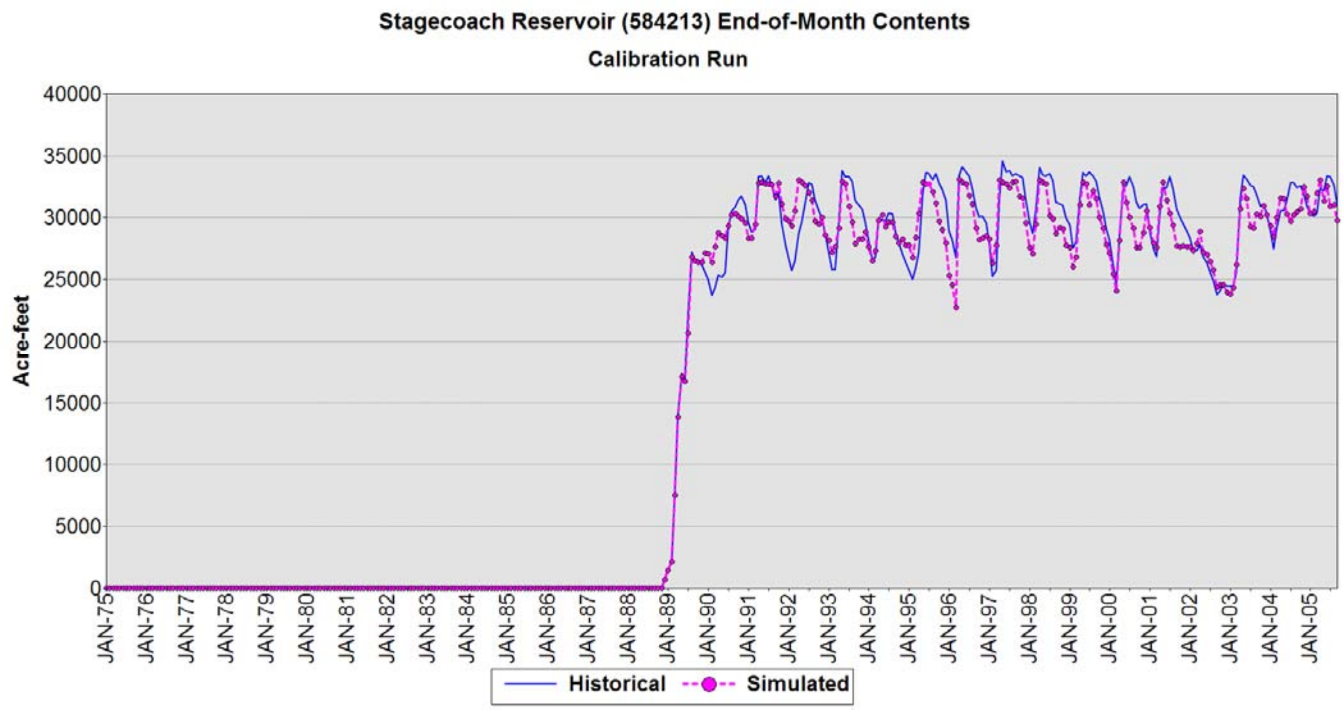


Figure 7.10 Reservoir Calibration – Stagecoach Reservoir

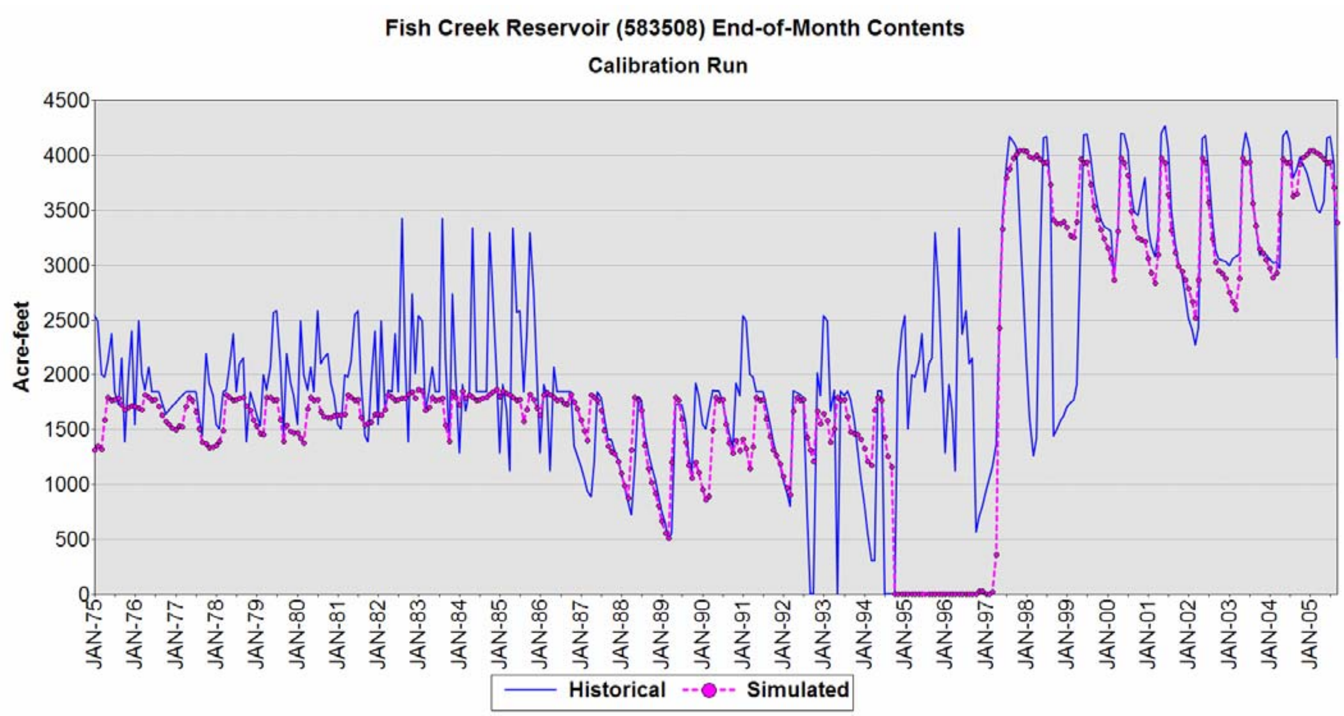


Figure 7.11 Reservoir Calibration - Fish Creek Reservoir

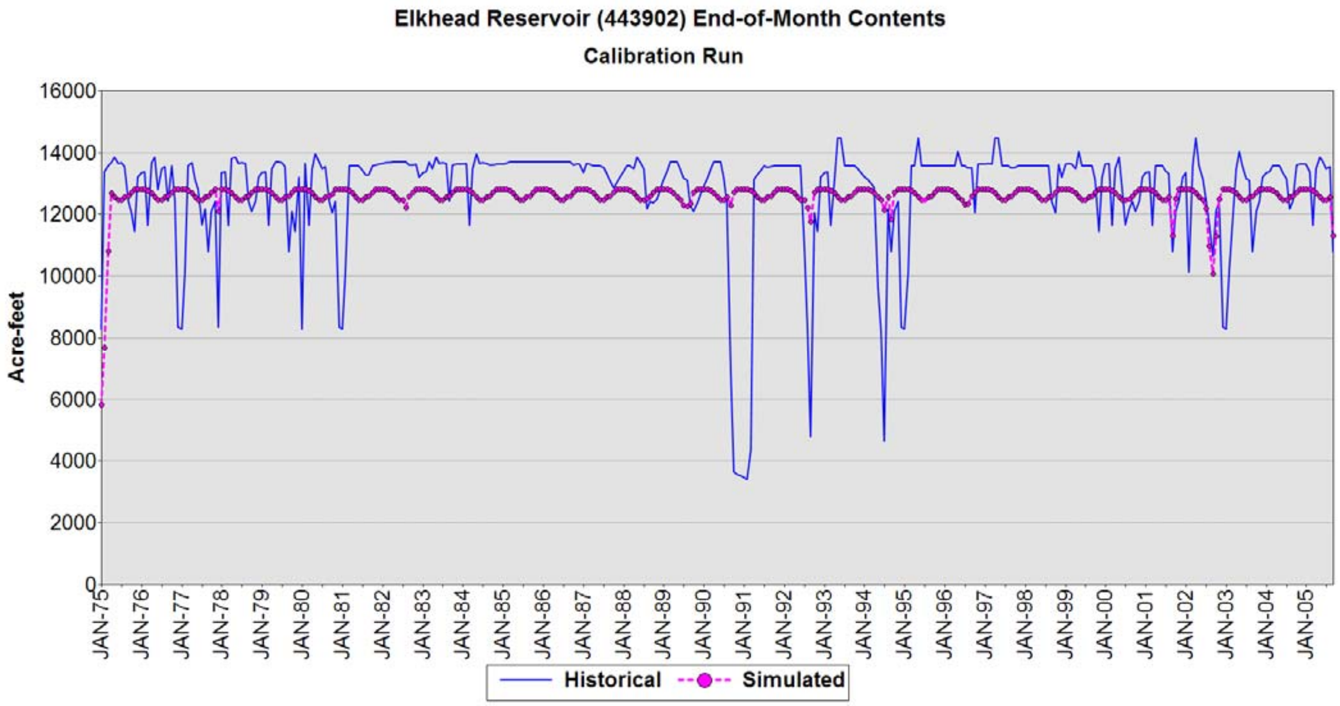


Figure 7.12 Reservoir Calibration – Elkhead Reservoir

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Appendix A

Aggregation of Irrigation Diversion Structures

1. Yampa River Aggregated Irrigation Structures
StateCU and Water Budget Maintenance - Task 10

2. CDSS Memorandum Sub task 3.03
Yampa River Aggregated Irrigation Structures

3. CDSS Memorandum Sub task 3.04
Yampa River Basin Add Aggregated Irrigation Structures To Network

Note: Memoranda in this Appendix are historical. They were produced when irrigation structures were aggregated and introduced into the model for the first time. Details may have changed through successive refinement and calibration, but the general approach remains the same. Details for the current model can be verified by reviewing DMI command files and Statemod input files.

CDSS Memorandum
Final

To: Ray Alvarado

From: LRE, Erin Wilson and Jennifer Ashworth

Subject: Yampa River Aggregated Irrigation Structures
StateCU and Water Budget Maintenance - Task 10

Date: March 30, 2004

Introduction

The original CRDSS StateMod and StateCU modeling efforts were based on the 1993 irrigated acreage coverage developed during initial CRDSS efforts. An irrigated acreage assessment representing year 2000 was recently performed for the CRDSS (western slope) basins. In each of the four Water Divisions (4, 5, 6, and 7), a portion of the 2000 acreage was tied to structures that did not have identified acreage in the 1993 coverage, therefore are not currently represented in the CRDSS models. In addition, structures that were identified as "Key" during the initial CRDSS efforts, in part based on irrigated acreage from the 1993 assessment were no longer shown as irrigated in 2000. As part of this task, key and aggregate structure lists for the western slope basins were revised to include 100 percent of the irrigated acreage based on both the 1993 and 2000 assessment.

As part of the re-aggregation task, discrepancies in both the 1993 and 2000 irrigated acreages were identified. These discrepancies included:

- 1993 irrigated parcels were not assigned to a water source (structure)
- 1993 and 2000 parcels irrigating the same lands were assigned to different water sources
- Structures identified as "Key" during efforts based on the 1993 coverage were not shown as irrigated in 2000
- Structure identifiers were incorrectly assigned to water districts where the acreage is located, instead of where the headgate is located. For example, acreage located in water district 40 was assigned by the water commissioner to structure 519. In the 2000 irrigated acreage coverage, the full WDID was entered as 4000519. However, the headgate for this structure is located in water district 41, and the correct WDID is 4100519.

Identified discrepancies were highlighted, and maps were sent to the Division Engineers for review. Both the 1993 and 2000 irrigated acreage coverages in each Water Division were revised based on the Division Engineers' comments prior to revising the key and aggregated structures.

Approach

The following approach was followed to update the designation of key and aggregated irrigated structures in the Yampa basin.

1. Move Key structures to aggregations for future model updated based on comments received from the Division Engineer. In general, Key structures were removed if the Division Engineer indicated that they no longer irrigated lands in 2000 or where incorrectly assigned to irrigated lands in 1993.

2. Aggregate remaining irrigation structures identified in either the 1993 or 2000 irrigated acreage coverages based on the aggregate spatial boundaries defined during the previous Yampa modeling effort, as described in memorandum "Subtask 2.03 Yampa River Aggregated Irrigation Structures, September 4, 1996."

Results

Table 1 indicates the number of structures in the updated aggregation and provides a comparison of the aggregated acreage from the previous modeling effort to the acreage assigned to the aggregation based on the 1993 Updated GIS coverage and the 2000 GIS coverage.

Table 1
Updated Aggregation Summary

Aggregation ID	Aggregation Name	# of Structures	Previous Acres	1993 Acres	2000 Acres
58_ADY001	Upper Bear River	12	292	527	600
58_ADY002	Chimney Creek	23	952	930	628
58_ADY003	Bear River above Hunt Creek	29	882	1,292	1,409
58_ADY004	Bear River above Stagecoach	29	661	874	802
58_ADY005	Yampa River above Steamboat	54	1,163	1,488	1,427
58_ADY006	Elk River near Clark	16	609	623	737
58_ADY007	Middle Elk River	45	1,062	2,633	1,571
58_ADY008	Lower Elk River	38	672	1,476	831
57_ADY009	Trout Creek	30	474	919	525
57_ADY010	Yampa River near Hayden	20	166	368	258
57_ADY011	Yampa River above Elkhead	21	485	1,035	657
44_ADY012	Elkhead Creek	17	437	639	606
44_ADY013	Yampa River bl Craig	38	1,204	1,786	1,645
44_ADY014	East Fork Williams Fork	36	1,493	1,818	1,105
44_ADY015	South Fork Williams Fork	23	1,024	769	298
44_ADY016	Williams Fork	41	435	1,588	710
44_ADY017	Milk Creek above G Spring	6	966	517	247

44_ADY018	Milk Creek	17	684	1,104	1,160
44_ADY019	Yampa River near Maybell	28	1,388	1,039	1,555
54_ADY020	Little Snake river near Slater	23	714	1,757	1,519
54_ADY021	Little Snake River above Slater	23	1,686	1,015	1,132
54_ADY022	Slater Creek	22	3,982	1,686	1,669
54_ADY023	Little Snake above Dry Gulch	22	365	4,326	4,321
54_ADY024	Little Snake river near Lily	8	555	552	921
44_ADY025	Yampa River at Deerlodge	24	48	701	623
55_ADY026	Yampa River at Green River	4	1,879	108	48
56_ADY027	Green River	40	716	2,173	1,774
Total		689	24,994	33,740	28,779

Several structures identified as Key in the previous CRDSS efforts are now included in aggregated structures, included as a "divsystem", or removed from the model network as follows:

- 4400519 – Yellow Jacket Ditch No 2. This structure had no acreage assigned in the 2000 coverage. Diversion comments indicated that water was not available in 2000.
- 4400538 – Averill Ditch. This structure had no acreage assigned in the 2000 coverage. Diversion records ended in 1994.
- 4400670 – J W Kellogg Ditch 2. This structure had no acreage assigned in the 2000 coverage. Diversion comments indicated that water was not available in 2000.
- 4400765 – South Side Ditch. This structure shows large diversions, but is only tied to about 19 acres. Water commissioner was unable to provide information; therefore the lands were moved to an aggregation.
- 4400828 – Mock Ditch No 3. This structure did not have irrigated lands or diversion records in either 1993 or 2000. Remove from model.
- 5400572 – Slater Park Ditch No 3. The lands under this structure can be irrigated by 5400574 (Slater Park Ditch No 5). Water commissioner recommends combining these two structures into a "divsystem" with 5400574 as primary structure.
- 5700513 – Connell Ditch. This structure was washed out in 2001 and is not expected to be irrigated in the future.
- 5800549 – Borland Vail Ditch. This structure had no acreage in the 2000 coverage. It did not divert water in either 1993 or 2000.
- 5800589 – Coal Creek Ditch. This structure had no acreage or diversion records in 2000.
- 5800791 – Muddy Ditch 1. This structure had no acreage in the 2000 coverage. Diversion records end in 1998.

Figure 1 shows the spatial boundaries of each aggregation. **Exhibit A**, attached, lists the diversion structures represented in each aggregate.

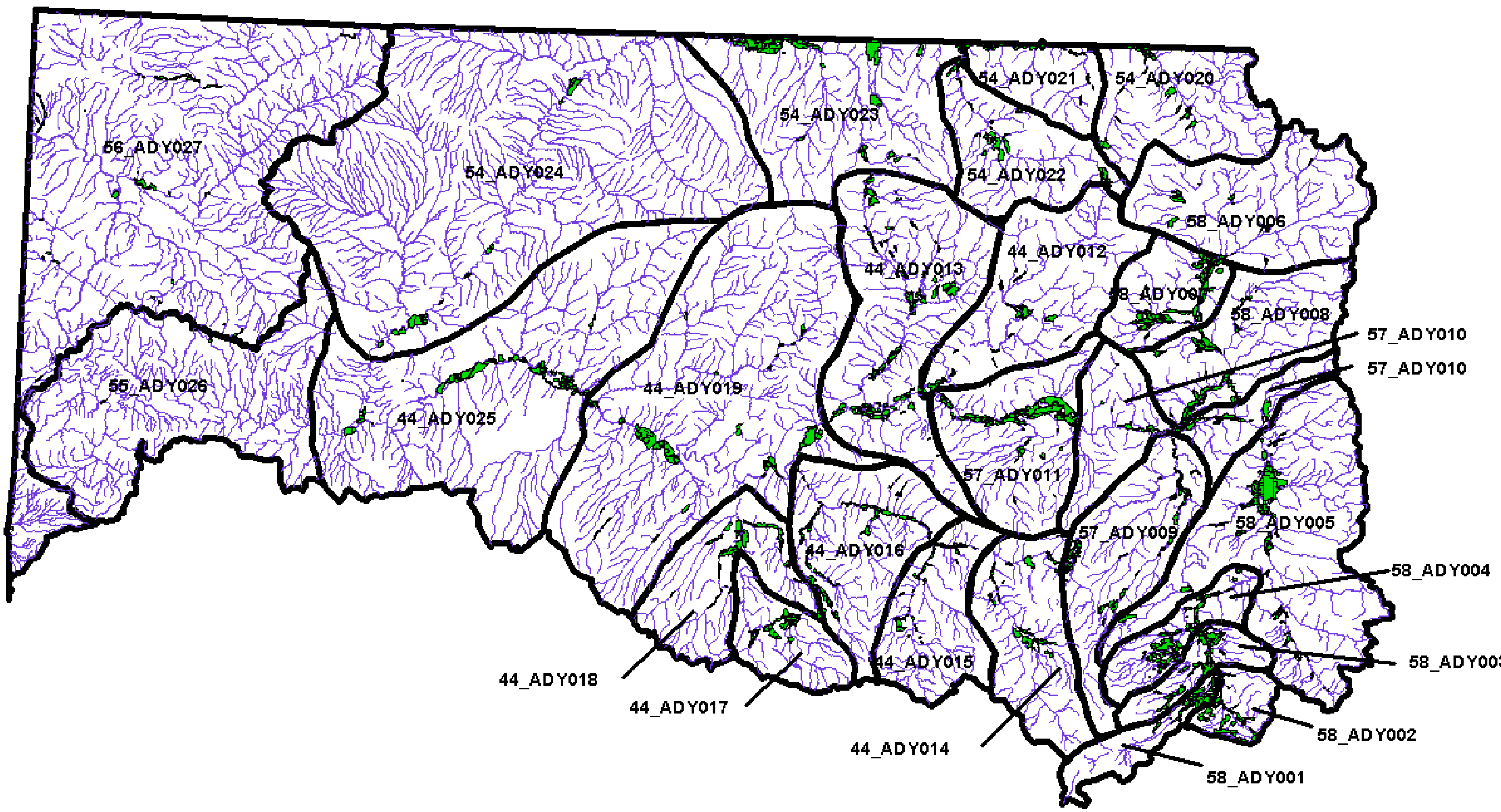

Figure 1 – Aggregate Structure Boundaries

Table 2 shows the estimated total irrigated acreage associated with key and aggregated structures, by water district, for the original 1993 coverage, the updated 1993 coverage, and the 2000 coverage. The irrigated acreage decreased by about 5 percent between the updated 1993 coverage and the 2000 coverage. As shown above, the decrease was in acreage assigned to both key structures and aggregated structures.

Table 2
Yampa River Basin Acreage

Water District	Original 1993 Acreage	Updated 1993 Acreage	2000 Acreage
44	27,176	28,729	29,996
54	13,578	14,677	14,373
55	1,541	1,793	2,384
56	1,879	2,173	1,774
57	9,448	10,660	9,126
58	29,066	36,023	32,101
Total	82,688	94,054	89,755

Comments and Concerns

None.

Recommendations

We recommend that consultants or State personnel performing future irrigated acreage updates understand the modeling concept of Key versus Aggregated structures. During updates, each Key structure should either be assigned to irrigated acreage, or an adequate explanation provided.

EXHIBIT A

Diversion Structures in Aggregates

Aggregation ID	Aggregation Name	WDID	1993 Acres	2000 Acres
58_ADY001	Upper Bear River	5800524	0.00	9.90
		5800528	18.80	16.10
		5800589	123.20	0.00
		5800596	23.80	13.50
		5800624	13.60	0.00
		5800630	109.40	103.20
		5800698	54.90	60.20
		5800699	34.80	46.40
		5800723	51.30	238.00
		5800741	56.00	102.40
		5800796	27.40	0.00
		5800819	13.40	10.60
58_ADY002	Chimney Creek	5800501	130.50	0.00
		5800533	18.60	29.60
		5800552	57.10	59.80
		5800598	52.30	38.80
		5800602	10.80	26.90
		5800636	17.90	0.00
		5800660	8.20	0.00
		5800710	23.60	41.70
		5800712	0.00	17.60
		5800802	8.00	19.70
		5800867	43.10	24.50
		5800871	6.10	7.80
		5800887	193.20	0.00
		5800904	3.90	7.10
		5800929	9.10	18.40
		5800931	2.60	7.10
		5800932	26.20	0.00
		5801190	49.10	64.10
		5801403	48.30	19.40
		5801405	78.20	128.30
		5801406	96.80	103.70
		5801409	46.00	0.00
		5801446	0.00	13.70
58_ADY003	Bear River above Hunt Creek	5800540	85.00	68.30
		5800543	58.20	54.70
		5800615	28.10	65.30
		5800620	6.80	8.10
		5800676	11.90	0.00
		5800689	101.80	99.30
		5800691	45.80	58.60
		5800692	86.20	85.70
		5800725	53.70	49.80

		5800732	12.60	16.10
		5800750	0.90	0.00
		5800770	7.90	291.10
		5800771	46.70	0.00
		5800772	5.90	61.20
		5800781	52.40	0.00
		5800820	56.30	0.00
		5800827	56.20	0.00
		5800828	33.30	119.10
		5800875	19.60	41.50
		5800883	22.30	0.00
		5800921	44.10	49.20
		5800934	34.10	214.00
		5800935	67.00	0.00
		5800938	18.30	0.00
		5800969	3.40	0.00
		5801102	12.30	18.50
		5801598	2.30	0.00
		5802435	1.50	0.00
		5803547	317.30	108.50
58_ADY004	Bear River above Stagecoach	5800522	16.10	47.30
		5800544	4.90	6.60
		5800566	142.80	183.50
		5800573	81.10	67.10
		5800575	20.40	30.10
		5800592	11.90	0.00
		5800704	4.50	0.00
		5800748	12.00	14.30
		5800764	64.60	50.40
		5800765	26.30	0.00
		5800775	2.30	0.00
		5800812	22.30	20.60
		5800816	5.30	0.00
		5800817	1.20	0.00
		5800838	23.20	18.80
		5800843	18.90	31.40
		5800873	30.40	37.10
		5800898	13.40	0.00
		5801070	5.90	0.00
		5801081	15.30	26.60
		5801086	4.80	15.40
		5801200	94.60	0.00
		5801399	6.70	0.00
		5801451	0.00	5.80
		5801541	76.60	86.40
		5801689	22.50	29.90
		5801710	66.00	130.40
		5802268	3.50	0.00
		5803564	76.20	0.00

58_ADY005	Yampa River above Steamboat	5800503	6.40	0.00
		5800509	27.30	53.30
		5800512	37.00	0.00
		5800519	36.00	0.00
		5800545	16.10	20.70
		5800550	18.10	0.00
		5800551	12.70	0.00
		5800567	70.90	0.00
		5800593	86.00	0.00
		5800606	23.60	0.00
		5800631	186.80	200.90
		5800641	117.20	52.20
		5800664	143.80	0.00
		5800675	25.00	0.00
		5800697	10.20	4.90
		5800702	19.60	38.20
		5800703	18.90	29.30
		5800755	49.70	16.40
		5800786	30.40	0.00
		5800790	52.00	0.00
		5800791	78.20	0.00
		5800794	35.90	42.00
		5800803	15.50	77.60
		5800815	18.80	24.20
		5800825	11.40	12.50
		5800850	0.00	52.80
		5800856	3.60	0.00
		5800859	44.20	52.50
		5800862	6.20	3.90
		5800884	1.00	0.00
		5800894	68.20	54.70
		5800905	21.70	27.10
		5800918	7.80	0.00
		5800927	0.00	423.60
		5800956	31.10	39.20
		5801072	6.70	10.00
		5801211	1.60	0.00
		5801212	2.50	0.00
		5801213	3.90	0.00
		5801214	6.00	0.00
		5801255	4.90	0.00
		5801477	1.80	0.00
		5801478	0.80	0.00
		5801562	10.00	17.70
		5801591	79.90	112.80
		5801616	2.00	0.00
		5801656	8.90	0.00
		5801868	0.00	17.10
		5802004	3.50	0.00

		5802422	9.70	0.00
		5802423	6.10	34.70
		5802564	1.80	0.00
		5803569	0.20	0.00
		5803826	6.00	8.90
58_ADY006	Elk River near Clark	5800580	4.50	8.80
		5800587	47.50	53.70
		5800595	0.00	17.90
		5800613	0.00	18.70
		5800651	15.40	0.00
		5800653	195.00	250.30
		5800754	37.30	31.80
		5800784	26.40	18.20
		5800833	23.00	10.70
		5800835	72.00	133.20
		5800842	103.30	100.20
		5800909	38.70	29.60
		5801690	9.30	0.00
		5801703	46.30	48.20
		5801746	3.90	0.00
		5801878	0.00	16.10
58_ADY007	Middle Elk River	5701068	43.50	0.00
		5800513	11.00	0.00
		5800549	301.20	0.00
		5800565	142.30	59.90
		5800578	10.90	0.00
		5800579	32.40	0.00
		5800616	25.10	0.00
		5800617	36.00	33.90
		5800619	60.90	75.90
		5800647	70.90	28.70
		5800648	69.00	0.00
		5800657	258.70	0.00
		5800658	105.60	216.70
		5800671	61.00	71.00
		5800678	112.40	0.00
		5800688	102.90	211.50
		5800706	52.20	53.80
		5800751	24.30	21.20
		5800759	21.10	0.00
		5800760	28.00	35.50
		5800779	60.20	79.80
		5800793	103.20	0.00
		5800800	61.60	65.40
		5800810	29.60	0.00
		5800824	3.80	0.00
		5800857	57.30	0.00
		5800861	151.70	0.00
		5800864	73.70	75.70

		5800865	33.10	38.00
		5800880	21.40	51.60
		5800881	91.90	129.20
		5800910	10.80	29.60
		5800911	9.00	9.50
		5801044	22.20	26.40
		5801094	33.10	0.00
		5801096	9.20	0.00
		5801389	7.30	0.00
		5801452	0.50	0.00
		5801595	118.90	101.30
		5801596	31.40	46.40
		5801685	3.60	0.00
		5801784	0.00	94.70
		5802233	0.90	0.00
		5802413	75.80	0.00
		5803520	53.20	15.30
58_ADY008	Lower Elk River	5800514	130.30	0.00
		5800516	6.60	0.00
		5800534	6.60	0.00
		5800537	47.60	48.60
		5800584	10.20	0.00
		5800670	13.70	8.90
		5800677	30.30	39.00
		5800686	32.90	0.00
		5800743	24.60	7.30
		5800746	52.70	54.90
		5800747	40.10	0.00
		5800768	2.60	0.00
		5800789	39.90	45.40
		5800797	119.70	102.70
		5800804	10.40	0.00
		5800829	137.40	130.30
		5800837	13.60	0.00
		5800848	6.60	0.00
		5800849	3.80	5.20
		5800869	121.10	0.00
		5800878	134.90	0.00
		5800906	125.20	163.60
		5800907	6.10	0.00
		5800919	0.80	0.00
		5800940	146.80	144.60
		5800994	12.30	0.00
		5800995	5.50	0.00
		5801008	0.50	0.00
		5801038	18.40	0.00
		5801039	17.10	0.00
		5801095	76.80	47.30
		5801151	8.60	5.90

		5801550	2.80	0.00
		5802340	8.30	0.00
		5802341	37.60	0.00
		5802353	4.80	0.00
		5802381	0.30	0.00
		5803519	18.20	27.10
57_ADY009	Trout Creek	5700506	21.30	0.00
		5700507	38.60	12.70
		5700513	109.20	67.70
		5700518	24.40	33.70
		5700521	12.60	43.90
		5700543	35.20	0.00
		5700549	64.10	0.00
		5700550	38.10	17.40
		5700552	13.60	10.60
		5700556	77.00	0.00
		5700565	20.00	31.80
		5700578	68.00	74.30
		5700581	31.80	0.00
		5700593	26.60	0.00
		5700594	10.30	0.00
		5700598	14.40	17.40
		5700599	42.00	40.30
		5700600	23.40	0.00
		5700601	45.60	6.90
		5700612	0.00	67.10
		5700617	20.60	0.00
		5700620	60.00	11.10
		5700621	20.70	19.30
		5700749	9.20	9.70
		5700750	32.70	0.00
		5701013	16.90	25.90
		5701048	12.50	0.00
		5703001	9.70	9.60
		5703541	0.00	15.90
		5703549	20.90	9.50
57_ADY010	Yampa River near Hayden	5700540	36.70	0.00
		5700567	4.70	0.00
		5700568	1.50	0.00
		5700603	11.30	14.30
		5700642	12.60	0.00
		5700675	38.40	42.70
		5700785	0.40	0.00
		5703516	7.30	16.60
		5800548	32.60	39.40
		5800716	0.20	0.00
		5800719	0.80	0.00
		5800742	17.90	0.00
		5800792	2.20	0.00

		5801045	17.60	18.00
		5801428	40.00	54.80
		5801621	58.90	0.00
		5801724	0.20	0.00
		5802117	79.40	72.00
		5802193	0.30	0.00
		5802502	5.40	0.00
57_ADY011	Yampa River above Elkhead	4400852	9.00	17.80
		5700502	10.70	0.00
		5700509	46.80	0.00
		5700522	88.50	14.70
		5700527	0.00	77.80
		5700536	96.10	0.00
		5700537	120.40	69.20
		5700547	70.20	175.90
		5700551	180.90	93.80
		5700586	101.80	0.00
		5700618	0.00	79.90
		5700628	63.90	0.00
		5700639	58.40	0.00
		5700752	16.80	31.60
		5700786	14.60	0.00
		5701057	64.80	0.00
		5701059	38.50	0.00
		5702078	3.40	0.00
		5702088	1.70	50.60
		5702125	28.70	45.30
		5703775	19.60	0.00
44_ADY012	Elkhead Creek	4400508	34.50	0.00
		4400649	28.20	35.10
		4400725	206.50	258.20
		4400840	22.20	39.90
		4400841	12.10	11.50
		4400842	29.00	34.20
		4400843	13.50	12.00
		4401083	0.00	12.50
		4401084	12.50	0.00
		4401188	47.90	74.90
		4401962	0.00	28.90
		4402099	10.40	0.00
		4402207	0.00	65.80
		4403926	8.80	0.00
		4404437	96.20	0.00
		5700569	40.60	33.20
		5702046	76.60	0.00
44_ADY013	Yampa River bl Craig	4400513	45.30	0.00
		4400516	63.20	94.70
		4400542	36.70	47.40
		4400659	12.40	0.00

		4400689	85.70	0.00
		4400697	59.20	65.80
		4400704	161.40	312.60
		4400710	34.60	33.50
		4400771	5.50	0.00
		4400783	15.00	15.00
		4400791	38.50	0.00
		4400800	50.20	50.20
		4400805	188.60	0.00
		4400817	53.10	44.30
		4400834	0.00	218.70
		4400836	149.20	14.20
		4400853	33.90	0.00
		4400857	19.00	19.00
		4400871	5.80	0.00
		4400931	0.00	25.30
		4401067	11.30	0.00
		4401102	12.40	10.40
		4401275	32.90	35.90
		4401434	132.50	142.70
		4401775	0.00	19.00
		4401924	174.90	184.80
		4402042	2.10	0.00
		4402059	32.80	0.00
		4402100	5.10	0.00
		4402116	0.00	20.70
		4402161	1.10	0.00
		4402371	76.00	51.80
		4403686	154.20	185.40
		4403824	25.40	0.00
		4405015	48.50	39.80
		4405016	0.00	13.30
		5700564	13.60	0.00
		5702133	6.30	0.00
44_ADY014	East Fork Williams Fork	4400507	68.90	0.00
		4400543	49.30	33.30
		4400544	9.90	4.00
		4400545	8.80	0.00
		4400546	16.10	16.50
		4400547	0.00	19.90
		4400560	15.10	0.00
		4400563	65.30	0.00
		4400571	20.90	0.00
		4400600	171.00	327.80
		4400603	18.00	14.90
		4400605	119.60	79.00
		4400608	0.00	25.10
		4400639	15.40	0.00
		4400640	9.50	0.00

		4400701	58.00	0.00
		4400703	68.30	29.80
		4400708	13.10	0.00
		4400709	27.20	0.00
		4400737	0.00	16.90
		4400738	126.30	0.00
		4400743	0.00	19.40
		4400755	78.30	88.70
		4400759	335.70	119.90
		4400761	181.00	0.00
		4400780	0.00	38.10
		4400781	2.30	0.00
		4400787	48.00	38.80
		4400815	0.00	9.80
		4400818	35.70	0.00
		4400924	0.00	36.00
		4401068	9.90	0.00
		4401069	9.00	0.00
		4402107	29.10	0.00
		5700500	29.70	0.00
		5700562	178.20	186.60
44_ADY015	South Fork Williams Fork	4400520	11.50	0.00
		4400521	89.10	0.00
		4400531	17.70	0.00
		4400554	21.10	0.00
		4400565	17.70	0.00
		4400567	12.70	0.00
		4400569	47.50	68.90
		4400615	39.50	0.00
		4400653	15.80	0.00
		4400658	20.40	0.00
		4400667	24.70	0.00
		4400671	53.20	0.00
		4400672	16.40	0.00
		4400683	20.70	0.00
		4400690	22.40	0.00
		4400727	66.70	0.00
		4400756	61.10	63.40
		4400758	16.00	26.30
		4400764	42.80	139.40
		4400773	40.10	0.00
		4400774	58.60	0.00
		4400776	49.80	0.00
		4400807	3.10	0.00
44_ADY016	Williams Fork	4400501	52.20	0.00
		4400504	6.30	0.00
		4400512	46.30	0.00
		4400515	20.30	68.90
		4400538	232.80	0.00

		4400539	63.50	0.00
		4400540	23.60	0.00
		4400556	100.50	176.50
		4400591	73.40	143.10
		4400592	85.40	0.00
		4400609	24.70	0.00
		4400646	44.20	0.00
		4400654	6.50	0.00
		4400655	5.80	0.00
		4400662	22.00	0.00
		4400669	67.00	108.10
		4400670	78.30	0.00
		4400684	27.40	0.00
		4400726	0.00	84.90
		4400728	19.00	0.00
		4400746	20.50	0.00
		4400762	53.60	0.00
		4400765	19.20	19.60
		4400769	18.40	0.00
		4400802	40.30	0.00
		4400850	74.90	41.00
		4400866	15.00	0.00
		4400915	4.20	0.00
		4401183	51.00	0.00
		4401270	1.50	0.00
		4401281	27.90	0.00
		4401356	19.20	25.80
		4401393	6.30	0.00
		4401414	0.00	11.60
		4401418	6.70	0.00
		4401447	5.50	0.00
		4402030	4.00	0.00
		4402171	30.10	30.50
		4402284	27.40	0.00
		4403682	83.20	0.00
		4405007	80.30	0.00
44_ADY017	Milk Creek above G Spring	4400519	60.40	0.00
		4400530	289.00	247.30
		4400551	5.60	0.00
		4400552	18.30	0.00
		4400668	114.70	0.00
		4400760	28.80	0.00
44_ADY018	Milk Creek	4400506	169.70	588.70
		4400525	0.00	31.40
		4400526	18.40	0.00
		4400610	52.90	126.00
		4400656	161.60	167.10
		4400664	7.30	0.00
		4400666	238.70	0.00

		4400673	7.60	0.00
		4400715	155.90	173.40
		4400733	29.50	39.70
		4400767	57.20	0.00
		4400768	32.20	0.00
		4400782	55.50	0.00
		4401108	59.60	34.00
		4402225	4.70	0.00
		4402226	13.90	0.00
		4402227	39.10	0.00
44_ADY019	Yampa River near Maybell	4400555	102.40	219.40
		4400557	74.90	71.70
		4400579	118.80	164.30
		4400641	0.00	159.70
		4400674	12.80	10.90
		4400713	53.90	78.80
		4400742	47.70	56.60
		4400745	95.20	59.90
		4400798	10.10	0.00
		4400808	0.00	31.60
		4400809	10.00	0.00
		4401272	53.50	49.20
		4401288	28.20	123.80
		4401361	37.70	22.70
		4401366	8.40	0.00
		4401376	3.60	0.00
		4401392	0.00	7.00
		4401705	0.00	4.70
		4401706	0.00	8.80
		4402134	20.90	25.20
		4402313	7.70	0.00
		4402377	29.70	31.60
		4403721	0.00	77.40
		4403722	41.30	25.00
		4403736	205.90	212.80
		4404453	8.50	9.80
		4405053	43.30	104.10
		4405056	24.20	0.00
54_ADY020	Little Snake river near Slater	5400501	38.20	0.00
		5400506	45.60	0.00
		5400508	36.30	0.00
		5400509	0.00	54.60
		5400510	226.90	226.30
		5400511	41.80	0.00
		5400522	33.90	0.00
		5400523	13.50	0.00
		5400528	108.40	108.30
		5400533	49.50	41.70
		5400534	31.70	0.00

		5400536	16.70	11.70
		5400538	330.90	0.00
		5400557	69.80	77.50
		5400576	70.30	0.00
		5400577	79.90	125.50
		5400580	131.30	150.20
		5400581	24.90	0.00
		5400585	65.80	64.20
		5400586	58.20	42.60
		5401107	206.50	189.50
		5401108	76.70	108.20
		5401117	0.00	319.00
54_ADY021	Little Snake River above Slater	5400500	56.30	64.00
		5400503	23.40	25.10
		5400512	0.00	11.00
		5400513	145.90	126.90
		5400524	12.00	11.80
		5400526	47.30	41.70
		5400539	39.70	48.00
		5400541	59.90	59.90
		5400547	0.00	66.10
		5400550	19.90	32.80
		5400551	44.30	73.90
		5400556	18.60	0.00
		5400562	40.50	45.30
		5400563	44.40	38.30
		5400566	240.20	209.30
		5400578	62.90	103.80
		5400711	17.40	9.30
		5400719	0.00	3.60
		5401038	0.00	18.60
		5401070	85.40	84.60
		5401075	17.70	17.70
		5402047	33.50	34.20
		5402119	5.20	6.30
54_ADY022	Slater Creek	5400504	84.70	173.90
		5400505	105.90	162.30
		5400517	241.70	258.90
		5400518	263.20	272.00
		5400519	339.40	305.50
		5400520	67.30	70.60
		5400540	51.80	38.70
		5400542	118.40	100.00
		5400544	28.90	28.10
		5400545	40.20	32.00
		5400546	2.90	0.00
		5400552	30.10	56.60
		5400565	7.30	8.30
		5400567	25.00	79.20

		5400569	66.30	0.00
		5400573	31.70	0.00
		5400584	62.10	0.00
		5400588	40.50	43.10
		5400625	17.30	11.40
		5402077	24.00	0.00
		5402085	24.30	28.40
		5402091	12.60	0.00
54_ADY023	Little Snake above Dry Gulch	5400515	405.30	121.10
		5400516	153.00	155.60
		5400527	22.90	67.50
		5400537	332.20	453.50
		5400558	97.40	78.70
		5400559	0.00	155.30
		5400590	389.40	405.40
		5400593	229.40	202.60
		5400653	0.00	30.30
		5401044	0.00	52.70
		5401045	551.10	15.60
		5401057	235.30	235.30
		5401058	0.00	482.80
		5401073	543.90	541.70
		5401076	1,047.70	1,046.50
		5401081	81.40	0.00
		5402068	92.30	92.10
		5402071	0.00	124.40
		5402075	75.00	0.00
		5402086	11.80	11.80
		5402128	37.90	47.70
		5405032	20.40	0.00
54_ADY024	Little Snake river near Lily	5500502	57.10	0.00
		5500503	32.40	26.90
		5500505	49.00	44.60
		5500514	84.50	83.90
		5500516	87.30	64.40
		5501011	111.80	110.00
		5501081	0.00	591.40
		5502031	130.20	0.00
44_ADY025	Yampa River at Deerlodge	4400529	113.90	126.90
		4400561	45.80	50.00
		4400719	45.20	36.40
		4400720	124.90	96.60
		4400721	34.40	46.80
		4400722	36.70	37.30
		4400730	74.80	70.20
		4400766	14.30	0.00
		4401088	0.60	0.00
		4401115	1.00	0.00
		4401268	0.00	42.20

		4401397	4.90	14.80
		4401409	0.00	5.50
		4401776	0.00	7.60
		4401777	0.00	3.60
		4401778	0.00	6.70
		4401779	0.00	6.90
		4401780	0.00	1.80
		4401781	0.00	17.50
		4402025	61.80	0.00
		4402037	31.60	52.40
		4403679	45.60	0.00
		4405013	60.90	0.00
		5501023	4.10	0.00
55_ADY026	Yampa River at Green River	5500510	60.10	0.00
		5502034	48.10	14.90
		5502035	0.00	14.90
		5502037	0.00	18.30
56_ADY027	Green River	5600551	89.90	0.00
		5600552	24.30	29.30
		5600503	60.20	60.30
		5600521	127.60	121.40
		5600524	57.30	52.40
		5600525	7.90	0.00
		5600527	11.60	0.00
		5600528	24.60	25.80
		5600532	60.90	0.00
		5600533	37.80	37.00
		5600534	0.00	1.10
		5600535	40.50	0.00
		5600536	20.90	21.90
		5600561	13.20	0.00
		5600562	0.00	50.40
		5600563	48.10	0.00
		5600564	77.00	0.00
		5600566	82.90	83.10
		5600568	52.30	50.80
		5600570	345.30	12.90
		5600572	82.80	124.20
		5600574	11.50	0.00
		5600583	157.10	0.00
		5600584	0.00	231.10
		5600585	27.10	144.70
		5600586	36.90	32.20
		5600587	42.90	46.60
		5600589	5.80	0.00
		5600595	18.80	13.40
		5600596	13.30	9.50
		5600598	33.90	34.30
		5600599	148.50	152.50

		5600615	25.20	0.00
		5600621	29.50	29.60
		5600622	2.90	0.00
		5600623	19.90	0.00
		5601045	46.00	46.30
		5601180	276.90	363.20
		5603713	11.60	0.00
		5605006	0.00	0.40
Total			33,740	28,779

CDSS MEMORANDUM

TO: File

FROM: Revised by Ray Alvarado 3/99

Meg Frantz

SUBJECT: **Sub task 3.03 - Yampa River Aggregated Irrigation Structures**

Introduction

This memo describes the approach and results of Sub task 3.03, Aggregate Irrigation Structures. The objective of this task was as follows:

> *Determine which diversion structures should be grouped together and decide where the node representing each group's aggregated operations should fit into the river network.*

Approach

Aggregation Criteria Twenty-seven aggregation boundaries were identified for the Yampa and Green Rivers. These were selected based primarily on gage and baseflow node location, critical administrative reaches, endangered species instream flow reaches, and on an objective that aggregations not exceed 1000 acres. While the scope anticipated 82 aggregation nodes, the State advised Boyle, based upon experience in the White River, that approximately 25 nodes would be more appropriate. This number is approximately the total Phase IIIa irrigated land divided by 1000.

Several aggregation groupings were adopted, in consultation with the State, in spite of being greater than 1000 acres:

- 58_ADY005 Yampa River above Steamboat (1163 acres) Allowed for aggregation from one mainstem gage to the next one, not far out of line from the 1000-acre objective

- 44_ADY013 Yampa River below Craig (1203 acres) Allowed for aggregation of Fortification Creek with the mainstem, and ended at a significant gage

- 44_ADY014 East Fork Williams Fork (1492 acres) Subdividing further would have meant adding a tributary and adding significant work related to baseflow generation

- 54_ADY020 Little Snake River near Slater, CO (1388 acres), 54_ADY022 Slater Creek (1686 acres), and 54_ADY023 Little Snake River above Dry Gulch (3982 acres) Many large parcels in this area were not modeled explicitly in Phase II, some lands irrigated in Colorado are under Wyoming diversions and rights (and vice versa), Kent Holt is working on trying to straighten out and summarize operations along the State line but that information is not now available, leaving large amounts of land aggregated is the only practical way to approach Little Snake River within this project.

- 56_ADY027 Green River (1879 acres) Modeling the Green River in detail is not an objective, however we want to model consumptive use within the State of Colorado, therefore aggregate

The larger number of acres in the aggregations listed above allowed for higher spatial resolution on the river above Stagecoach Reservoir. This is the area that has been administered historically.

Excluded Parcels Two parcels of land included in the Phase IIIa irrigated land database are located in the Colorado Basin, in the Egeria Creek basin. The structure number assigned to these parcels in the database is 580887. However, the lands appear in the Colorado Basin database with a different structure assignment. After consulting with the State it was decided that these two parcels should be excluded from the Phase IIIa Yampa model.

Three parcels of land included in the Phase IIIa irrigated land database are located wholly within Wyoming. These were excluded from the aggregations. One parcel lies in both States and was left in the model because the larger part is in Colorado.

Three parcels identified as Phase IIIa lands in the spatial database had already been included in the Phase II model. The three parcels compose all irrigated land under two structures. The parcels were excluded from the aggregations. This duplication was identified by **watright**.

Data Checks To verify that no structures appeared in two aggregation groups, the list of structures represented by the aggregations was sorted in an Excel spreadsheet. A 0/1 flag was set for each, reflecting whether the structure id was the same (1) as the previous structure or not (0). The sum of the column of flags was zero. Therefore, the State did not need to resolve any duplicate structure id's. The acreage column in the Excel spreadsheet was summed to verify that total acreage in the aggregation list matched total acreage from the Phase IIIa irrigated lands Arcview tables. This verified that no parcels had been somehow dropped.

Division Review On December 2, 1996, we met with Mr. Kent Holt, assistant division engineer for Division 6, to review the aggregation of irrigation structures in the Yampa basin. A map of the aggregation boundaries was presented and the criteria used in setting those boundaries were discussed. Mr. Holt had no objection to the aggregations as presented.

Results

A 36" x 48" map of the aggregation boundaries, showing Phase II and Phase IIIa lands and baseflow nodes as well was delivered to the State in October. Exhibit 1 is a tabulation of the aggregations, the number of parcels in each, and the total irrigated land for each grouping. Exhibit 2 lists the diversion structures represented by each node.

Aggregation nodes were given the id "WD_ADYxxx", for Aggregated Diversion Yampa. The value xxx reflects stream order, beginning with 58_ADY001 on the Upper Bear River. Names of downstream gages were used for the node name where appropriate. These names and id's are consistent with the convention set in the White River.

In all cases, the nodes representing the aggregated lands were placed in the model at the most downstream position within the aggregated area. Incorporating nodes into the network and structure files is described in Section D.3.

Comments and concerns

Executing sub task 3.03 raised some concern about the current model of the Little Snake River basin. The Little Snake River flows more or less parallel to the Wyoming/Colorado State line, leaving and re-entering Colorado twice before turning south to the Yampa mainstem. In this area, there are irrigated lands in Wyoming which are served by Colorado rights and vice versa. Kent Holt is working on summarizing operations in Wyoming, but that information is not available at this point. The State may want to address several issues related to this area, some of which might be better undertaken when Mr. Holt has completed his project:

- Many large parcels in this area were not modeled explicitly in the Phase II model. Some of them are on tributaries to the Little Snake or in the headwaters section, well within the State, and are served by Colorado rights. The parcels are large enough that one would expect the associated water rights to be above the Phase II cutoff, but this has not been verified.

- At the State's direction, lands that are identified as Phase IIIa irrigated lands in the spatial database, but which lie in Wyoming, have been excluded from the Phase IIIa model. However, some parcels lying wholly in Wyoming were included in the Phase II model.

- For the purpose of the Phase IIIa model, Phase IIIa lands within Colorado but close toWyoming will be aggregated and served by whatever Colorado water rights are associated with those lands. In the long term, the State may want to treat the whole border area in a more detailed way. The degree of resolution in this area should be coordinated with the degree of resolution in the estimate of consumptive use represented at the "Wyoming Demand" nodes.

EXHIBIT 1

Yampa River Basin
Aggregation Structures
Summary Table

Aggregation Id	Aggregation Name	Count	Acres
58_ADY001	58_ADY001_UpperBearRiver	11	292.45
58_ADY002	58_ADY002_ChimneyCreek	29	951.66
58_ADY003	58_ADY003_BearRabvHuntCk	33	881.55
58_ADY004	58_ADY004_BearRabvStagecoa	31	661.03
58_ADY005	58_ADY005_YampaRabvSteambt	50	1162.78
58_ADY006	58_ADY006_ElkRivernrClark	15	609.42
58_ADY007	58_ADY007_MiddleElkRiver	23	1061.86
58_ADY008	58_ADY008_LowerElkRiver	30	671.92
57_ADY009	57_ADY009_TroutCreek	16	473.50
58_ADY010	58_ADY010_YampaRnrHayden	13	166.23
57_ADY011	57)ADY011_YampaRabvElkhead	14	485.20
44_ADY012	44_ADY012_ElkheadCreek	16	437.08
44_ADY013	44_ADY013_YampaRbelCraig	26	1203.87
44_ADY014	44_ADY014_EfkWilliamsFork	36	1492.51
44_ADY015	44_ADY015_SFkWilliamsFork	25	682.72
44_ADY016	44_ADY016_WilliamsFork	42	1024.07
44_ADY017	44_ADY017_MilkCkabvGSpring	6	435.16
44_ADY018	44_ADY018_MilkCreek	19	965.89
44_ADY019	44_ADY019_YampaRnrMaybell	20	683.90
54_ADY020	54_ADY020_LsnakeRnrSlater	22	1387.90
54_ADY021	54_ADY021_LsnakeRabvSlater	24	714.44
54_ADY022	54_ADY022_SlaterCreek	26	1685.67
54_ADY023	54_ADY023_LsnakeabvDryGlch	47	3981.54
54_ADY024	54_ADY024_LsnakeRnrLily	6	364.88
44_ADY025	44_ADY025_YampaR@DeerLodge	16	555.40
55_ADY026	55_ADY026_YampaR@GreenR	1	48.09
56_ADY027	56_ADY027_GreenRiver	36	1878.89
	Excluded	8	715.65
Total		641	25675.25
Total excluding tow parcels in Egeria Creek Basin, three parcels in Wyoming, and three Phase II parcels		633	24959.61

EXHIBIT 2

Yampa River Basin
Aggregated Structures

Aggregation	Aggregation Name	Wd_id	Acres	Count
58_ADY001	58_ADY001_UpperBearRiver	580528	18.80	1
	58_ADY001_UpperBearRiver	580596	23.79	1
	58_ADY001_UpperBearRiver	580624	13.58	1
	58_ADY001_UpperBearRiver	580630	109.38	2
	58_ADY001_UpperBearRiver	580699	34.84	1
	58_ADY001_UpperBearRiver	580723	51.30	1
	58_ADY001_UpperBearRiver	580796	27.38	3
	58_ADY001_UpperBearRiver	580819	13.39	1
58_ADY002	58_ADY002_ChimneyCreek	580501	130.52	2
	58_ADY002_ChimneyCreek	580533	18.58	1
	58_ADY002_ChimneyCreek	580552	57.11	1
	58_ADY002_ChimneyCreek	580598	52.34	1
	58_ADY002_ChimneyCreek	580602	10.83	3
	58_ADY002_ChimneyCreek	580636	17.87	1
	58_ADY002_ChimneyCreek	580660	8.23	1
	58_ADY002_ChimneyCreek	580698	54.85	1
	58_ADY002_ChimneyCreek	580710	128.06	2
	58_ADY002_ChimneyCreek	580741	55.97	1
	58_ADY002_ChimneyCreek	580802	7.96	1
	58_ADY002_ChimneyCreek	580867	43.10	2
	58_ADY002_ChimneyCreek	580871	6.14	1
	58_ADY002_ChimneyCreek	580904	3.86	1
	58_ADY002_ChimneyCreek	580929	9.06	2
	58_ADY002_ChimneyCreek	580931	2.62	1
	58_ADY002_ChimneyCreek	580932	26.17	1
	58_ADY002_ChimneyCreek	581190	49.12	2
	58_ADY002_ChimneyCreek	581403	48.26	1
	58_ADY002_ChimneyCreek	581405	78.21	1
	58_ADY002_ChimneyCreek	581406	96.83	1
	58_ADY002_ChimneyCreek	581409	45.96	1
58_ADY003	58_ADY003_BearRabvHuntCk	580540	84.99	1
	58_ADY003_BearRabvHuntCk	580543	58.20	2
	58_ADY003_BearRabvHuntCk	580615	28.05	2
	58_ADY003_BearRabvHuntCk	580620	6.79	1
	58_ADY003_BearRabvHuntCk	580689	101.85	2
	58_ADY003_BearRabvHuntCk	580691	45.84	1
	58_ADY003_BearRabvHuntCk	580692	86.17	1
	58_ADY003_BearRabvHuntCk	580725	53.69	2
	58_ADY003_BearRabvHuntCk	580732	12.56	1
	58_ADY003_BearRabvHuntCk	580750	0.93	1
	58_ADY003_BearRabvHuntCk	580770	7.87	1
	58_ADY003_BearRabvHuntCk	580771	46.71	1
	58_ADY003_BearRabvHuntCk	580772	5.93	1

Yampa River Basin
Aggregated Structures

Aggregation	Aggregation Name	Wd_id	Acres	Count
	58_ADY003_BearRabvHuntCk	580820	33.08	1
	58_ADY003_BearRabvHuntCk	580827	56.22	1
	58_ADY003_BearRabvHuntCk	580828	30.00	2
	58_ADY003_BearRabvHuntCk	580875	19.58	1
	58_ADY003_BearRabvHuntCk	580883	22.33	3
	58_ADY003_BearRabvHuntCk	580921	44.13	1
	58_ADY003_BearRabvHuntCk	580934	34.10	1
	58_ADY003_BearRabvHuntCk	580935	66.99	2
	58_ADY003_BearRabvHuntCk	580938	18.28	1
	58_ADY003_BearRabvHuntCk	580969	3.44	1
	58_ADY003_BearRabvHuntCk	581102	12.34	1
	58_ADY003_BearRabvHuntCk	582435	1.48	1
58_ADY004	58_ADY004_BearRabvStagecoa	580522	16.14	1
	58_ADY004_BearRabvStagecoa	580544	4.90	1
	58_ADY004_BearRabvStagecoa	580573	26.07	1
	58_ADY004_BearRabvStagecoa	580575	20.41	1
	58_ADY004_BearRabvStagecoa	580592	11.86	1
	58_ADY004_BearRabvStagecoa	580748	11.97	4
	58_ADY004_BearRabvStagecoa	580764	64.61	1
	58_ADY004_BearRabvStagecoa	580765	26.31	1
	58_ADY004_BearRabvStagecoa	580812	22.26	1
	58_ADY004_BearRabvStagecoa	580816	5.27	1
	58_ADY004_BearRabvStagecoa	580817	1.17	1
	58_ADY004_BearRabvStagecoa	580838	23.22	1
	58_ADY004_BearRabvStagecoa	580843	18.93	1
	58_ADY004_BearRabvStagecoa	580873	30.39	1
	58_ADY004_BearRabvStagecoa	580898	13.41	1
	58_ADY004_BearRabvStagecoa	581070	5.85	1
	58_ADY004_BearRabvStagecoa	581081	15.31	1
	58_ADY004_BearRabvStagecoa	581086	4.84	1
	58_ADY004_BearRabvStagecoa	581200	94.61	1
	58_ADY004_BearRabvStagecoa	581399	6.69	1
	58_ADY004_BearRabvStagecoa	581541	76.56	2
	58_ADY004_BearRabvStagecoa	581689	22.50	1
	58_ADY004_BearRabvStagecoa	581710	65.97	3
	58_ADY004_BearRabvStagecoa	582268	3.52	1
	58_ADY004_BearRabvStagecoa	583564	68.25	1
58_ADY005	58_ADY005_YampaRabvSteambt	580509	27.27	1
	58_ADY005_YampaRabvSteambt	580512	37.01	1
	58_ADY005_YampaRabvSteambt	580519	35.97	1
	58_ADY005_YampaRabvSteambt	580545	16.15	1
	58_ADY005_YampaRabvSteambt	580593	86.00	2
	58_ADY005_YampaRabvSteambt	580606	23.62	1
	58_ADY005_YampaRabvSteambt	580631	100.44	3
	58_ADY005_YampaRabvSteambt	580641	117.17	3

Yampa River Basin
Aggregated Structures

Aggregation	Aggregation Name	Wd_id	Acres	Count
	58_ADY005_YampaRabvSteambt	580664	143.79	2
	58_ADY005_YampaRabvSteambt	580675	24.99	1
	58_ADY005_YampaRabvSteambt	580697	10.17	1
	58_ADY005_YampaRabvSteambt	580702	19.60	1
	58_ADY005_YampaRabvSteambt	580755	49.72	1
	58_ADY005_YampaRabvSteambt	580786	30.42	1
	58_ADY005_YampaRabvSteambt	580790	51.96	1
	58_ADY005_YampaRabvSteambt	580794	35.93	1
	58_ADY005_YampaRabvSteambt	580803	15.48	1
	58_ADY005_YampaRabvSteambt	580825	11.41	1
	58_ADY005_YampaRabvSteambt	580856	3.61	1
	58_ADY005_YampaRabvSteambt	580859	44.17	1
	58_ADY005_YampaRabvSteambt	580862	6.17	1
	58_ADY005_YampaRabvSteambt	580884	1.01	1
	58_ADY005_YampaRabvSteambt	580894	68.21	1
	58_ADY005_YampaRabvSteambt	580905	21.69	1
	58_ADY005_YampaRabvSteambt	580956	31.12	1
	58_ADY005_YampaRabvSteambt	581072	6.72	1
	58_ADY005_YampaRabvSteambt	581211	1.64	1
	58_ADY005_YampaRabvSteambt	581212	2.47	1
	58_ADY005_YampaRabvSteambt	581213	3.92	1
	58_ADY005_YampaRabvSteambt	581214	5.97	1
	58_ADY005_YampaRabvSteambt	581477	1.77	1
	58_ADY005_YampaRabvSteambt	581478	0.84	1
	58_ADY005_YampaRabvSteambt	581562	10.04	1
	58_ADY005_YampaRabvSteambt	581591	79.86	4
	58_ADY005_YampaRabvSteambt	581616	1.97	1
	58_ADY005_YampaRabvSteambt	581656	8.91	1
	58_ADY005_YampaRabvSteambt	582004	3.51	1
	58_ADY005_YampaRabvSteambt	582422	9.69	1
	58_ADY005_YampaRabvSteambt	582423	6.11	1
	58_ADY005_YampaRabvSteambt	583569	0.25	1
	58_ADY005_YampaRabvSteambt	583826	6.03	1
58_ADY006	58_ADY006_ElkRivernrClark	580580	4.53	1
	58_ADY006_ElkRivernrClark	580587	47.51	1
	58_ADY006_ElkRivernrClark	580651	15.44	1
	58_ADY006_ElkRivernrClark	580653	194.96	3
	58_ADY006_ElkRivernrClark	580754	37.30	1
	58_ADY006_ElkRivernrClark	580784	26.41	1
	58_ADY006_ElkRivernrClark	580833	22.98	2
	58_ADY006_ElkRivernrClark	580835	71.99	2
	58_ADY006_ElkRivernrClark	580842	103.28	1
	58_ADY006_ElkRivernrClark	580909	38.73	1
	58_ADY006_ElkRivernrClark	581703	46.30	1
58_ADY007	58_ADY007_MiddleElkRiver	580565	129.50	2

Yampa River Basin
Aggregated Structures

Aggregation	Aggregation Name	Wd_id	Acres	Count
	58_ADY007_MiddleElkRiver	580578	10.91	1
	58_ADY007_MiddleElkRiver	580579	32.43	1
	58_ADY007_MiddleElkRiver	580619	60.92	1
	58_ADY007_MiddleElkRiver	580647	59.74	1
	58_ADY007_MiddleElkRiver	580657	258.67	1
	58_ADY007_MiddleElkRiver	580688	102.85	1
	58_ADY007_MiddleElkRiver	580706	52.19	1
	58_ADY007_MiddleElkRiver	580760	28.04	1
	58_ADY007_MiddleElkRiver	580857	57.25	1
	58_ADY007_MiddleElkRiver	580864	73.73	3
	58_ADY007_MiddleElkRiver	580865	33.12	1
	58_ADY007_MiddleElkRiver	580880	21.36	1
	58_ADY007_MiddleElkRiver	580881	91.87	3
	58_ADY007_MiddleElkRiver	580910	10.82	1
	58_ADY007_MiddleElkRiver	580911	8.99	1
	58_ADY007_MiddleElkRiver	581044	22.18	1
	58_ADY007_MiddleElkRiver	581389	7.29	1
58_ADY008	58_ADY008_LowerElkRiver	580516	6.64	1
	58_ADY008_LowerElkRiver	580534	6.56	1
	58_ADY008_LowerElkRiver	580537	23.66	1
	58_ADY008_LowerElkRiver	580670	13.75	1
	58_ADY008_LowerElkRiver	580743	24.56	1
	58_ADY008_LowerElkRiver	580746	52.72	1
	58_ADY008_LowerElkRiver	580747	40.09	1
	58_ADY008_LowerElkRiver	580768	2.57	1
	58_ADY008_LowerElkRiver	580789	39.89	2
	58_ADY008_LowerElkRiver	580797	119.69	4
	58_ADY008_LowerElkRiver	580804	10.40	1
	58_ADY008_LowerElkRiver	580837	13.63	1
	58_ADY008_LowerElkRiver	580878	134.86	4
	58_ADY008_LowerElkRiver	580906	125.22	1
	58_ADY008_LowerElkRiver	580919	0.76	1
	58_ADY008_LowerElkRiver	580994	12.33	1
	58_ADY008_LowerElkRiver	580995	5.53	1
	58_ADY008_LowerElkRiver	581008	0.49	1
	58_ADY008_LowerElkRiver	581038	18.36	1
	58_ADY008_LowerElkRiver	581039	17.14	2
	58_ADY008_LowerElkRiver	581550	2.82	1
	58_ADY008_LowerElkRiver	582381	0.26	1
57_ADY009	57_ADY009_TroutCreek	570507	17.67	1
	57_ADY009_TroutCreek	570518	24.43	1
	57_ADY009_TroutCreek	570543	35.24	1
	57_ADY009_TroutCreek	570550	20.44	1
	57_ADY009_TroutCreek	570552	13.60	1
	57_ADY009_TroutCreek	570556	77.00	1

Yampa River Basin
Aggregated Structures

Aggregation	Aggregation Name	Wd_id	Acres	Count
	57_ADY009_TroutCreek	570578	68.00	1
	57_ADY009_TroutCreek	570581	31.82	1
	57_ADY009_TroutCreek	570593	26.60	1
	57_ADY009_TroutCreek	570598	14.42	2
	57_ADY009_TroutCreek	570601	45.61	1
	57_ADY009_TroutCreek	570620	60.04	1
	57_ADY009_TroutCreek	570749	9.21	1
	57_ADY009_TroutCreek	571013	16.89	1
	57_ADY009_TroutCreek	571048	12.53	1
57_ADY010	57_ADY010_YampaRnrHayden	570603	11.33	1
	57_ADY010_YampaRnrHayden	570785	0.41	1
	57_ADY010_YampaRnrHayden	580548	32.64	2
	57_ADY010_YampaRnrHayden	580716	0.18	1
	57_ADY010_YampaRnrHayden	580719	0.84	1
	57_ADY010_YampaRnrHayden	580742	17.91	1
	57_ADY010_YampaRnrHayden	581045	17.58	1
	57_ADY010_YampaRnrHayden	581724	0.21	1
	57_ADY010_YampaRnrHayden	582117	79.40	2
	57_ADY010_YampaRnrHayden	582193	0.33	1
	57_ADY010_YampaRnrHayden	582502	5.41	1
57_ADY011	57_ADY011_YampaRabvElkhead	570509	46.84	2
	57_ADY011_YampaRabvElkhead	570522	88.46	3
	57_ADY011_YampaRabvElkhead	570547	70.22	1
	57_ADY011_YampaRabvElkhead	570551	127.00	2
	57_ADY011_YampaRabvElkhead	570628	63.85	1
	57_ADY011_YampaRabvElkhead	570639	58.41	2
	57_ADY011_YampaRabvElkhead	572088	1.75	1
	57_ADY011_YampaRabvElkhead	572125	28.68	2
44_ADY012	44_ADY012_ElkheadCreek	440508	34.49	1
	44_ADY012_ElkheadCreek	440649	28.24	2
	44_ADY012_ElkheadCreek	440725	206.52	1
	44_ADY012_ElkheadCreek	440840	35.70	4
	44_ADY012_ElkheadCreek	440841	12.05	1
	44_ADY012_ElkheadCreek	441084	12.45	1
	44_ADY012_ElkheadCreek	441188	47.86	3
	44_ADY012_ElkheadCreek	442099	10.44	1
	44_ADY012_ElkheadCreek	443926	8.76	1
	44_ADY012_ElkheadCreek	570569	40.56	1
44_ADY013	44_ADY013_YampaRbelCraig	440513	45.27	3
	44_ADY013_YampaRbelCraig	440516	47.95	2
	44_ADY013_YampaRbelCraig	440536	149.21	1
	44_ADY013_YampaRbelCraig	440542	27.31	2
	44_ADY013_YampaRbelCraig	440558	155.59	1
	44_ADY013_YampaRbelCraig	440689	85.68	2
	44_ADY013_YampaRbelCraig	440697	59.20	2

Yampa River Basin
Aggregated Structures

Aggregation	Aggregation Name	Wd_id	Acres	Count
	44_ADY013_YampaRbelCraig	440783	15.03	1
	44_ADY013_YampaRbelCraig	440791	38.46	1
	44_ADY013_YampaRbelCraig	440800	50.19	2
	44_ADY013_YampaRbelCraig	440805	188.60	1
	44_ADY013_YampaRbelCraig	440871	5.45	1
	44_ADY013_YampaRbelCraig	441102	12.42	1
	44_ADY013_YampaRbelCraig	441275	32.94	1
	44_ADY013_YampaRbelCraig	442042	2.07	1
	44_ADY013_YampaRbelCraig	442059	32.82	1
	44_ADY013_YampaRbelCraig	442371	76.04	1
	44_ADY013_YampaRbelCraig	443686	154.25	1
	44_ADY013_YampaRbelCraig	443824	25.40	1
44_ADY014	44_ADY014_EFkWilliamsFork	440507	68.91	1
	44_ADY014_EFkWilliamsFork	440543	49.33	2
	44_ADY014_EFkWilliamsFork	440545	8.78	2
	44_ADY014_EFkWilliamsFork	440546	16.15	1
	44_ADY014_EFkWilliamsFork	440563	65.35	1
	44_ADY014_EFkWilliamsFork	440571	20.87	2
	44_ADY014_EFkWilliamsFork	440600	171.01	3
	44_ADY014_EFkWilliamsFork	440603	15.04	1
	44_ADY014_EFkWilliamsFork	440605	113.55	3
	44_ADY014_EFkWilliamsFork	440639	15.44	1
	44_ADY014_EFkWilliamsFork	440640	9.46	1
	44_ADY014_EFkWilliamsFork	440701	58.00	1
	44_ADY014_EFkWilliamsFork	440708	13.07	1
	44_ADY014_EFkWilliamsFork	440709	27.16	1
	44_ADY014_EFkWilliamsFork	440755	78.34	1
	44_ADY014_EFkWilliamsFork	440759	335.68	3
	44_ADY014_EFkWilliamsFork	440761	181.00	2
	44_ADY014_EFkWilliamsFork	440787	19.13	1
	44_ADY014_EFkWilliamsFork	441068	9.94	1
	44_ADY014_EFkWilliamsFork	441069	9.01	1
	44_ADY014_EFkWilliamsFork	442107	29.11	1
	44_ADY014_EFkWilliamsFork	570562	178.20	5
44_ADY015	44_ADY015_SFkWilliamsFork	440521	89.05	1
	44_ADY015_SFkWilliamsFork	440531	17.67	1
	44_ADY015_SFkWilliamsFork	440554	21.15	1
	44_ADY015_SFkWilliamsFork	440565	17.73	1
	44_ADY015_SFkWilliamsFork	440567	12.67	1
	44_ADY015_SFkWilliamsFork	440569	47.48	1
	44_ADY015_SFkWilliamsFork	440615	39.54	1
	44_ADY015_SFkWilliamsFork	440653	15.78	2
	44_ADY015_SFkWilliamsFork	440658	20.35	1
	44_ADY015_SFkWilliamsFork	440667	24.72	1
	44_ADY015_SFkWilliamsFork	440671	53.21	1

Yampa River Basin
Aggregated Structures

Aggregation	Aggregation Name	Wd_id	Acres	Count
	44_ADY015_SFkWilliamsFork	440683	20.67	1
	44_ADY015_SFkWilliamsFork	440690	14.01	1
	44_ADY015_SFkWilliamsFork	440727	66.72	4
	44_ADY015_SFkWilliamsFork	440756	11.60	1
	44_ADY015_SFkWilliamsFork	440758	16.01	1
	44_ADY015_SFkWilliamsFork	440764	42.80	1
	44_ADY015_SFkWilliamsFork	440773	40.08	1
	44_ADY015_SFkWilliamsFork	440774	58.57	1
	44_ADY015_SFkWilliamsFork	440776	49.83	1
	44_ADY015_SFkWilliamsFork	440807	3.09	1
44_ADY016	44_ADY016_WilliamsFork	440501	52.19	1
	44_ADY016_WilliamsFork	440539	63.51	1
	44_ADY016_WilliamsFork	440540	23.57	1
	44_ADY016_WilliamsFork	440556	100.53	2
	44_ADY016_WilliamsFork	440591	73.37	1
	44_ADY016_WilliamsFork	440592	33.89	2
	44_ADY016_WilliamsFork	440609	24.71	1
	44_ADY016_WilliamsFork	440655	5.80	1
	44_ADY016_WilliamsFork	440669	66.97	1
	44_ADY016_WilliamsFork	440728	18.99	1
	44_ADY016_WilliamsFork	440746	20.48	2
	44_ADY016_WilliamsFork	440762	53.63	1
	44_ADY016_WilliamsFork	440769	18.36	1
	44_ADY016_WilliamsFork	440802	40.33	3
	44_ADY016_WilliamsFork	440850	74.92	4
	44_ADY016_WilliamsFork	440866	15.01	2
	44_ADY016_WilliamsFork	440915	4.21	1
	44_ADY016_WilliamsFork	441183	51.01	1
	44_ADY016_WilliamsFork	441270	1.52	1
	44_ADY016_WilliamsFork	441281	27.88	1
	44_ADY016_WilliamsFork	441356	19.17	2
	44_ADY016_WilliamsFork	441393	6.33	1
	44_ADY016_WilliamsFork	441418	6.73	1
	44_ADY016_WilliamsFork	442171	30.07	2
	44_ADY016_WilliamsFork	442284	27.38	1
	44_ADY016_WilliamsFork	443682	83.22	1
	44_ADY016_WilliamsFork	445007	80.30	5
44_ADY017	44_ADY017_MilkCkabvGSpring	440530	288.98	2
	44_ADY017_MilkCkabvGSpring	440551	5.58	1
	44_ADY017_MilkCkabvGSpring	440552	18.33	1
	44_ADY017_MilkCkabvGSpring	440668	114.65	1
44_ADY018	44_ADY018_MilkCreek	440506	161.66	1
	44_ADY018_MilkCreek	440526	18.37	2
	44_ADY018_MilkCreek	440610	52.87	3
	44_ADY018_MilkCreek	440656	94.45	1

Yampa River Basin
Aggregated Structures

Aggregation	Aggregation Name	Wd_id	Acres	Count
	44_ADY018_MilkCreek	440664	7.27	1
	44_ADY018_MilkCreek	440666	238.72	1
	44_ADY018_MilkCreek	440673	2.38	1
	44_ADY018_MilkCreek	440715	155.92	1
	44_ADY018_MilkCreek	440733	29.54	1
	44_ADY018_MilkCreek	440767	57.21	2
	44_ADY018_MilkCreek	440768	32.19	1
	44_ADY018_MilkCreek	440782	55.55	2
	44_ADY018_MilkCreek	441108	59.62	2
	44_ADY018_MilkCreek	442227	7.75	1
44_ADY019	44_ADY019_YampaRnrMaybell	440555	102.44	3
	44_ADY019_YampaRnrMaybell	440557	74.89	3
	44_ADY019_YampaRnrMaybell	440579	118.83	1
	44_ADY019_YampaRnrMaybell	440674	12.78	1
	44_ADY019_YampaRnrMaybell	440742	47.74	1
	44_ADY019_YampaRnrMaybell	440745	95.24	3
	44_ADY019_YampaRnrMaybell	441272	53.51	1
	44_ADY019_YampaRnrMaybell	441361	37.70	3
	44_ADY019_YampaRnrMaybell	442377	29.73	1
	44_ADY019_YampaRnrMaybell	443722	41.34	1
	44_ADY019_YampaRnrMaybell	443736	61.17	1
	44_ADY019_YampaRnrMaybell	444453	8.51	1
54_ADY020	54_ADY020_LSnakeRnrSlater	540506	45.58	1
	54_ADY020_LSnakeRnrSlater	540510	226.91	1
	54_ADY020_LSnakeRnrSlater	540528	108.42	4
	54_ADY020_LSnakeRnrSlater	540533	49.47	2
	54_ADY020_LSnakeRnrSlater	540536	16.71	2
	54_ADY020_LSnakeRnrSlater	540538	310.24	2
	54_ADY020_LSnakeRnrSlater	540576	70.31	1
	54_ADY020_LSnakeRnrSlater	540577	62.47	1
	54_ADY020_LSnakeRnrSlater	540580	131.29	1
	54_ADY020_LSnakeRnrSlater	540585	65.83	1
	54_ADY020_LSnakeRnrSlater	541107	224.00	5
	54_ADY020_LSnakeRnrSlater	541108	76.67	1
54_ADY021	54_ADY021_LSnakeRabvSlater	540503	23.41	1
	54_ADY021_LSnakeRabvSlater	540513	145.87	4
	54_ADY021_LSnakeRabvSlater	540524	11.99	1
	54_ADY021_LSnakeRabvSlater	540526	47.29	1
	54_ADY021_LSnakeRabvSlater	540539	39.69	1
	54_ADY021_LSnakeRabvSlater	540550	19.88	1
	54_ADY021_LSnakeRabvSlater	540551	44.33	1
	54_ADY021_LSnakeRabvSlater	540556	18.62	1
	54_ADY021_LSnakeRabvSlater	540562	40.55	2
	54_ADY021_LSnakeRabvSlater	540563	44.40	2
	54_ADY021_LSnakeRabvSlater	540578	62.88	1

Yampa River Basin
Aggregated Structures

Aggregation	Aggregation Name	Wd_id	Acres	Count
	54_ADY021_LSnakeRabvSlater	540707	85.42	2
	54_ADY021_LSnakeRabvSlater	540719	17.37	2
	54_ADY021_LSnakeRabvSlater	541075	17.73	1
	54_ADY021_LSnakeRabvSlater	542047	33.50	1
	54_ADY021_LSnakeRabvSlater	542119	5.20	1
	54_ADY021_LSnakeRabvSlater	545008	56.31	1
54_ADY022	54_ADY022_SlaterCreek	540504	84.73	1
	54_ADY022_SlaterCreek	540505	105.85	1
	54_ADY022_SlaterCreek	540517	241.67	2
	54_ADY022_SlaterCreek	540518	263.23	1
	54_ADY022_SlaterCreek	540519	339.44	1
	54_ADY022_SlaterCreek	540520	67.30	2
	54_ADY022_SlaterCreek	540540	51.77	1
	54_ADY022_SlaterCreek	540542	118.42	3
	54_ADY022_SlaterCreek	540544	28.91	1
	54_ADY022_SlaterCreek	540545	40.18	1
	54_ADY022_SlaterCreek	540546	2.93	1
	54_ADY022_SlaterCreek	540552	30.15	1
	54_ADY022_SlaterCreek	540565	7.28	1
	54_ADY022_SlaterCreek	540567	24.97	1
	54_ADY022_SlaterCreek	540569	66.35	1
	54_ADY022_SlaterCreek	540573	31.69	1
	54_ADY022_SlaterCreek	540584	62.12	1
	54_ADY022_SlaterCreek	540625	17.30	1
	54_ADY022_SlaterCreek	540688	40.54	1
	54_ADY022_SlaterCreek	542077	23.95	1
	54_ADY022_SlaterCreek	542085	24.30	1
	54_ADY022_SlaterCreek	542091	12.57	1
54_ADY023	54_ADY023_LSnakeabvDryGlch	540515	405.34	1
	54_ADY023_LSnakeabvDryGlch	540516	152.99	2
	54_ADY023_LSnakeabvDryGlch	540527	22.87	1
	54_ADY023_LSnakeabvDryGlch	540537	206.98	6
	54_ADY023_LSnakeabvDryGlch	540558	97.37	1
	54_ADY023_LSnakeabvDryGlch	540590	389.44	9
	54_ADY023_LSnakeabvDryGlch	540593	229.39	1
	54_ADY023_LSnakeabvDryGlch	541045	551.07	2
	54_ADY023_LSnakeabvDryGlch	541057	235.29	4
	54_ADY023_LSnakeabvDryGlch	541073	543.95	4
	54_ADY023_LSnakeabvDryGlch	541076	828.04	8
	54_ADY023_LSnakeabvDryGlch	541081	81.39	1
	54_ADY023_LSnakeabvDryGlch	542068	92.31	2
	54_ADY023_LSnakeabvDryGlch	542075	74.98	1
	54_ADY023_LSnakeabvDryGlch	542086	11.81	1
	54_ADY023_LSnakeabvDryGlch	542128	37.92	2
	54_ADY023_LSnakeabvDryGlch	545032	20.39	1

Yampa River Basin
Aggregated Structures

Aggregation	Aggregation Name	Wd_id	Acres	Count
55_ADY024	55_ADY024_LSnakeRnrLily	550503	32.40	2
	55_ADY024_LSnakeRnrLily	550505	48.97	1
	55_ADY024_LSnakeRnrLily	550514	84.45	1
	55_ADY024_LSnakeRnrLily	550516	87.29	1
	55_ADY024_LSnakeRnrLily	551011	111.77	1
44_ADY025	44_ADY025_YampaR@DeerLodge	440529	113.94	2
	44_ADY025_YampaR@DeerLodge	440561	45.78	1
	44_ADY025_YampaR@DeerLodge	440719	45.24	1
	44_ADY025_YampaR@DeerLodge	440720	124.94	1
	44_ADY025_YampaR@DeerLodge	440721	34.39	1
	44_ADY025_YampaR@DeerLodge	440722	12.30	1
	44_ADY025_YampaR@DeerLodge	440730	74.81	1
	44_ADY025_YampaR@DeerLodge	441088	0.58	1
	44_ADY025_YampaR@DeerLodge	441115	0.97	1
	44_ADY025_YampaR@DeerLodge	441397	4.89	1
	44_ADY025_YampaR@DeerLodge	442025	61.84	1
	44_ADY025_YampaR@DeerLodge	442037	31.63	3
	44_ADY025_YampaR@DeerLodge	551023	4.07	1
55_ADY026	55_ADY026_YampaR@GreenR	552034	48.09	1
56_ADY027	56_ADY027_GreenRiver	560503	60.17	1
	56_ADY027_GreenRiver	560521	127.59	1
	56_ADY027_GreenRiver	560524	57.28	1
	56_ADY027_GreenRiver	560525	7.93	1
	56_ADY027_GreenRiver	560527	11.58	1
	56_ADY027_GreenRiver	560528	24.62	1
	56_ADY027_GreenRiver	560533	33.93	1
	56_ADY027_GreenRiver	560536	57.81	2
	56_ADY027_GreenRiver	560561	13.25	1
	56_ADY027_GreenRiver	560563	48.13	1
	56_ADY027_GreenRiver	560564	76.99	2
	56_ADY027_GreenRiver	560570	428.05	3
	56_ADY027_GreenRiver	560583	157.15	1
	56_ADY027_GreenRiver	560585	27.15	2
	56_ADY027_GreenRiver	560587	42.91	1
	56_ADY027_GreenRiver	560589	5.82	1
	56_ADY027_GreenRiver	560595	18.80	1
	56_ADY027_GreenRiver	560596	13.35	1
	56_ADY027_GreenRiver	560597	37.82	1
	56_ADY027_GreenRiver	560599	148.45	1
	56_ADY027_GreenRiver	560621	29.54	1
	56_ADY027_GreenRiver	560622	2.86	1
	56_ADY027_GreenRiver	561180	276.94	4
	56_ADY027_GreenRiver	563713	11.61	1
	56_ADY027_GreenRiver	563921	45.96	1
	56_ADY027_GreenRiver	560532	60.94	2

Yampa River Basin
Aggregated Structures

Aggregation	Aggregation Name	Wd_id	Acres	Count
	56_ADY027_GreenRiver	560568	52.26	1
Out-of-basin		543968	245.75	2
		580887	193.18	2
		540537	125.23	1
In Phase 2		540592	60.85	2
		550507	90.64	1
Total (excludes out-of basin and Phase II lands)			24959.60	633
Total number of structures = 449				

TO: File

FROM: Roger Sonnichsen & Meg Frantz

SUBJECT: **Sub task 3.04 - Yampa River Basin Add aggregated irrigation structures to network**

Introduction

This memo describes the approach and results obtained under Sub task 3.04, Add Aggregated Structures to Network. The objective of this task was as follows:

Formalize addition of the aggregated irrigation structures, as identified in Sub task 3.03 to the model.

Approach and Results

Add Aggregated Irrigation Structures to Network: The Yampa River Basin Network of Exhibit 1 of Section D.1 shows how the 27 aggregated irrigation structures associated with Phase IIIa Yampa River Model were integrated into the river network. The aggregated structures that were placed just upstream of a gage were made base flow nodes. Base flow nodes require the area-precipitation parameter filled out in the .net file. The base flow area was calculated by subtracting out the upstream gaged area from the downstream gaged area. The base flow precipitation was calculated by subtracting from the downstream gage area-precipitation factor the upstream gages area-precipitation factor and dividing this value by the base flow area.

The aggregate node 58_ADY004 BearRabvStagecoa was placed upstream of node 584213, which is a Reservoir/base flow node. The area-precipitation factor of 133.73*19.762 for node 584213, was adopted for node 58_ADY004.

The aggregate node 56_ADY027 GreenRiver was also made a base flow node. Its area was calculated to be 877 sq-mi using ArcView and the map created in Sub task 3.02. The precipitation for node 56_ADY027 was estimated to be 13 inches from the Colorado Average Annual Precipitation 1951-1980 map. A setprf(56_ADY027,09260000) option was added to the Phase II command.net file, causing makenet to calculate base flow for the aggregated node 56_ADY027 GreenRiver from the nearby gage 09260000 Little Snake River near Lily.

A diversion node yampa.Lst was added just upstream of the terminus node. The node is required because **Statemod** does not permit return flows to the terminal node. The new node receives return flows from aggregated nodes 55_ADY026 and 56_ADY027.

The areas for gages 09260000 Little Snake River near Lily and 09260050 Yampa River at Deerlodge Park were changed to the area presented in the USGS Water Resources Data books. The area is 7,660 sq-mi for gage 09260050 and 3,730 sq-mi for gage 09260000. The area was changed to represent the total area above each gage including area in Wyoming. The average precipitation for both gages was assumed to be the same as for gage 09251000 Yampa River near Maybell, which is 18.4 inches. The value of 18.4 inches was assumed to represent the average precipitation over the total drainage area including the area in Wyoming. However precipitation maps for Wyoming were not used at this time as they were not readily available.

Makenet was run with the new .net file, using the command file option with the *command.net* file to create new .rin, .ris, and .rib files. These files in their final form are included in **Appendix A.** The model was checked for any added flows by looking at Table 9 Base flow summary in the **Statemod** output file **.xtb*, to verify that the gains were zero between the aggregated nodes and the next downstream node.

Comments

The Green River aggregated node was included in the model so that the model represents all consumptive use above the point where the Green River leaves Colorado. The baseflow assigned to this node represents flow generated within the state; it does not reflect gaged flow in Wyoming adjusted for either upstream use or reservoir operations. Consequently, the most downstream gage that was useful for calibrating the model was the Yampa River at Deer Lodge Park.

Appendix B

Aggregation of Non-Irrigation Structures

1. CDSS Memorandum Sub task 3.10
Yampa River Basin Aggregated Municipal and Industrial Use

2. CDSS Memorandum Sub task 3.11
Yampa River Basin Aggregated Reservoirs and Stock Ponds

3. CDSS Memorandum Sub task 2.09-12
Consumptive Use Model Non-Irrigation (Other Uses) Consumptive Uses and Losses in the Yampa River Basin

Note: Memoranda in this Appendix are historical. They were produced when non-irrigation structures were aggregated and introduced into the model for the first time. Details may have changed through successive refinement and calibration, but the general approach remains the same. Details for the current model can be verified by reviewing DMI command files and Statemod input files.

CDSS MEMORANDUM

TO: File

FROM: Revised by Ray Alvarado 3/99

Meg Frantz

SUBJECT: **Task 3.10 - Yampa River Basin Aggregated Municipal and Industrial Use**

Introduction

This memo describes the results of Sub task 3.10 Yampa River Basin Aggregated Municipal and Industrial Use. The objective of the task was as follows:

> *Aggregate municipal and industrial uses not explicitly modeled in Phase II to simulate their depletive effects in the basin.*

Approach

The aggregated municipal and industrial nodes are used in the Phase IIIa model to represent all consumptive use which is:

1. not explicitly modeled, and
2. not an irrigation direct diversion, reservoir storage, or evaporation from reservoirs and stockponds.

Total consumptive use in the Yampa basin was estimated in CRDSS Task 2.09-12, documented in the memorandum “Consumptive Use Model Non-Irrigation Consumptive Uses and Losses in the Yampa River Basin.” The approach in this task was to identify municipal and industrial consumptive use which was modeled explicitly in the Phase II model. These values were then subtracted from the estimated total consumptive use attributable to municipal, mineral, thermal electric, and livestock use, according to the above referenced memorandum. The aggregated M&I nodes in the Phase IIIa model represent the remaining amount of use.

Task Memorandum 2.09-12 summarizes transmountain diversions, as well as the uses mentioned above. The summary shows transbasin agricultural diversions to the Upper Colorado basin by the Dome Creek Ditch, which was not included in the Phase II model because it did not meet the cutoff criterion for key structures. It was decided that, as a general rule, transbasin diversions should be handled explicitly by the model. Therefore, Dome Creek and the Dome Creek Ditch were added to the model in conjunction with this task.

Results

M&I Consumptive Use in the Phase II Model: Exhibit 1 presents average annual diversions and depletions of seven municipal or industrial diversions in the Phase II model, for 1975 to 1991. The structures were identified by searching the direct flow diversion summary (Table 4.2.1a Yampa River Basin Model Water Resources Planning Model) for irrigated acreage of -999 or 0, or average annual efficiency of either 100 or 0 percent. Consumptive use values in the exhibit were taken from the Water Supply Summary (*.xsu) for the Phase II historical scenario, to which the modeled efficiency was applied to determine consumptive use. The exhibit also shows the County-HUC location of each structure.

Basinwide M&I Consumptive Use: Exhibit 2 summarizes the relevant tables of Task Memorandum 2.09-12, and assigns consumptive use to the three primary hydrologic units in the basin (14050001, 14050002, and 14050003). Exhibit 3 is a map showing the hydrologic units within the Yampa basin. While mineral and thermal electric consumption were presented in Task Memorandum 2.09-12 by hydrologic unit, municipal and livestock consumption were available only by county. This location breakdown in the original data provided a rationale for representing aggregated M&I consumption in the Phase IIIa model with three nodes, one for each of the primary hydrologic units. Consumptive use according to Task Memorandum 2.09-12 was thus assigned to hydrologic unit by the following rules:

- Hydrologic units for mineral resource and thermal electric consumptive use were taken directly from Task Memorandum 2.09-12.
- "Municipal" population was assigned to the appropriate hydrologic unit because municipality locations are known and discrete. All municipalities listed in Task Memorandum 2.09-12 are in hydrologic unit 14050001.
- "Rural" population for Garfield County was assigned to hydrologic unit 14050001, because all of Garfield County within the Yampa basin is contained in that unit.
- "Rural" population in Moffat, Rio Blanco, and Routt Counties was summed and split evenly among the three hydrologic units, because actual distribution is unknown.
- Basinwide livestock consumptive use was split evenly into thirds, and one third was assigned to each hydrologic unit.
- Thermal electric demands were left as quantified in Phase II.

Aggregated Consumptive Use for the Phase IIIa Model: Exhibit 4 shows two tables that show the difference between basinwide depletions by other uses ("Other CU") and the explicitly modeled M&I depletions ("Ph2 StateMod") at the basin wide level and the aggregated M&I node by water district. In order to preserve the basinwide estimate of other consumptive uses (Task Memo 2.09-12) as the basis of total consumptive use in the Phase IIIa model, "Total Difference" was taken as the algebraic sum of the negative municipal difference and the positive industrial difference, except for thermal electric, which was left constant, at 17063 acre-feet per year.

A time series of monthly demands for the study period was created by hand for each aggregated M&I node. Demand for every month in the study period was based on the work that BBC Research & Consulting did for the 1998 Yampa Valley Water Demand Study. The time series are in Statemod matrix format, in files named *44_AMY001.stm*, 55*_AMY003.stm*, *57_AMY001* and 58*_AMY001.stm*. These series were incorporated in the .ddh and .ddm files by using the -replace option in **demandts**. This process is described more fully in Task Memorandum 3.09.

The aggregated M&I nodes were located at the upper end of the water divisions since M&I use is used throughout the water districts.

Each aggregated M&I node was assigned a water right decree adequate to permit the maximum monthly demand, expressed in cfs. They were also each assigned an administration number of 1.0.

Specific steps followed in executing Sub task 3.10 are described in Exhibit 5**.**

Comment

There is a somewhat large discrepancy between consumptive use in the "thermal electric" use category, as reported in Task Memo 2.09-12, and the historical diversions (which are 100 percent depletive) of the Craig and Hayden power stations combined, as modeled in Phase II. Task Memo 2.09-12 reports average annual thermal electric use as 17,063 af/yr. Demand for the two power stations, which is based on historical diversions, totals 11,468 af/yr, for a difference of 5,595 af/yr. It is unlikely that a single large user was overlooked in the Phase II model, based on the research and interviews with water commissioners that were carried out as part of the Phase II effort. It is also unlikely that consumptive use for power generation is dispersed among many small users. Since only additional M&I uses, not quantified in Phase II, were being determined, the difference between thermal electric in Phase II and Task Memo 2.09-12 was ignored. It is believed that the thermal electric values used in Phase II are more accurate and were not changed.

EXHIBIT 1

M&I Consumptive Use in Phase II Model (Historical Scenario)
(values in acre-feet/year)

Water Supply Summary Output (yampaH.xsu file)

Station ID	County-HUC	Name	Efficiency (%)	Average Annual Diversions	Average Annual CU
Industrial					
440522	Moffat 14050001	Craig Sta D + PL	100	6443	6443
440695	Moffat 14050002	Maybell Mill Pipeline	100	117	117
570512	Routt 14050001	Colo Utilities D A PL	100	5025	5025
581583	Routt 14050001	HeadGate Derived From DI	0	2689	0
582374	Routt 14050001	Steamboat Ski snowmaking	20	52	10.4
	Industrial subtotal			14326	11595.4
Municipal					
440581	Moffat 14050001	Craig Water Supply PL	Monthly	1581	634
580642	Routt 14050001	Fish Cr Pipeline A	Monthly	1804	659.95
	Municipal subtotal			3385	1294
TOTAL				17711	12889.35

EXHIBIT 2

Summary of tables in Task Memorandum and assignment of Other CU to Hydrologic Unit

Municipal Use

from Tables 7 (Municipal Population), 8 (Rural Population), and 11(Municipal Consumptive Use)

		1985	1986	1987	1988	1989	1990	Average
14050001	Municipal pop. - all counties	16786	16873	16960	17046	17133	17220	17003
	Rural pop. - Garfield county	244	249	253	258	262	267	256
	Subtotal (14050001)	17030	17122	17213	17304	17395	17487	17259
	CU (subtotal / 16.1)							1072
Unknown	Rural pop. - Moffat	2746	2621	2495	2370	2244	2118	2432
	Rural pop. - Rio Blanco	169	167	165	163	162	160	164
	Rural pop. - Routt	4514	4494	4474	4454	4434	4414	4464
	Subtotal (Unknown hyd. unit)	7429	7282	7134	6987	6840	6692	7061
	CU (subtotal / 16.1)							439
	Municipal Use by hydrologic unit:							
14050001	CU for 14050001 + one-third of CU							1218.1
14050002	One third of CU for Unknown							146.2
14050003	One third of CU for Unknown							146.2
	Total							1511

Industrial Use

		1985	1986	1987	1988	1989	1990	Average
Table 3 - Livestock Consumptive Use by County								
	Garfield	10	10	10	10	10	10	10.0
	Moffat	329	322	314	333	351	370	336.5
	RioBlanco	48	48	48	48	47	47	47.7
	Routt	383	374	365	372	379	385	376.3
	Livestock use total							771
Table 12 - Mineral Resource Consumptive Use by hydrologic unit								
	14050001	986	979	972	965	959	952	968.8
	14050002	347	388	428	468	508	549	448.0
	14050003	213	244	276	307	338	370	291.3
	Mineral use total							1708
Table 13 - Thermal Electric Consumptive Use by hydrologic unit								
	14050001	15590	16220	16849	16875	18108	18738	17063.3
	ThermalElec use total							17063
	Industrial use by hydrologic unit:							0
14050001	One third of livestock CU + mineral CU + thermal electric CU							18289
14050002	One third of livestock CU + mineral CU							704.8
14050003	One third of livestock CU +mineral CU							548.2
	Total							19542

Notes:

1. Relationship "Municipal CU = population / 16.1" is from Task Memo 2.09-12

EXHIBIT 3

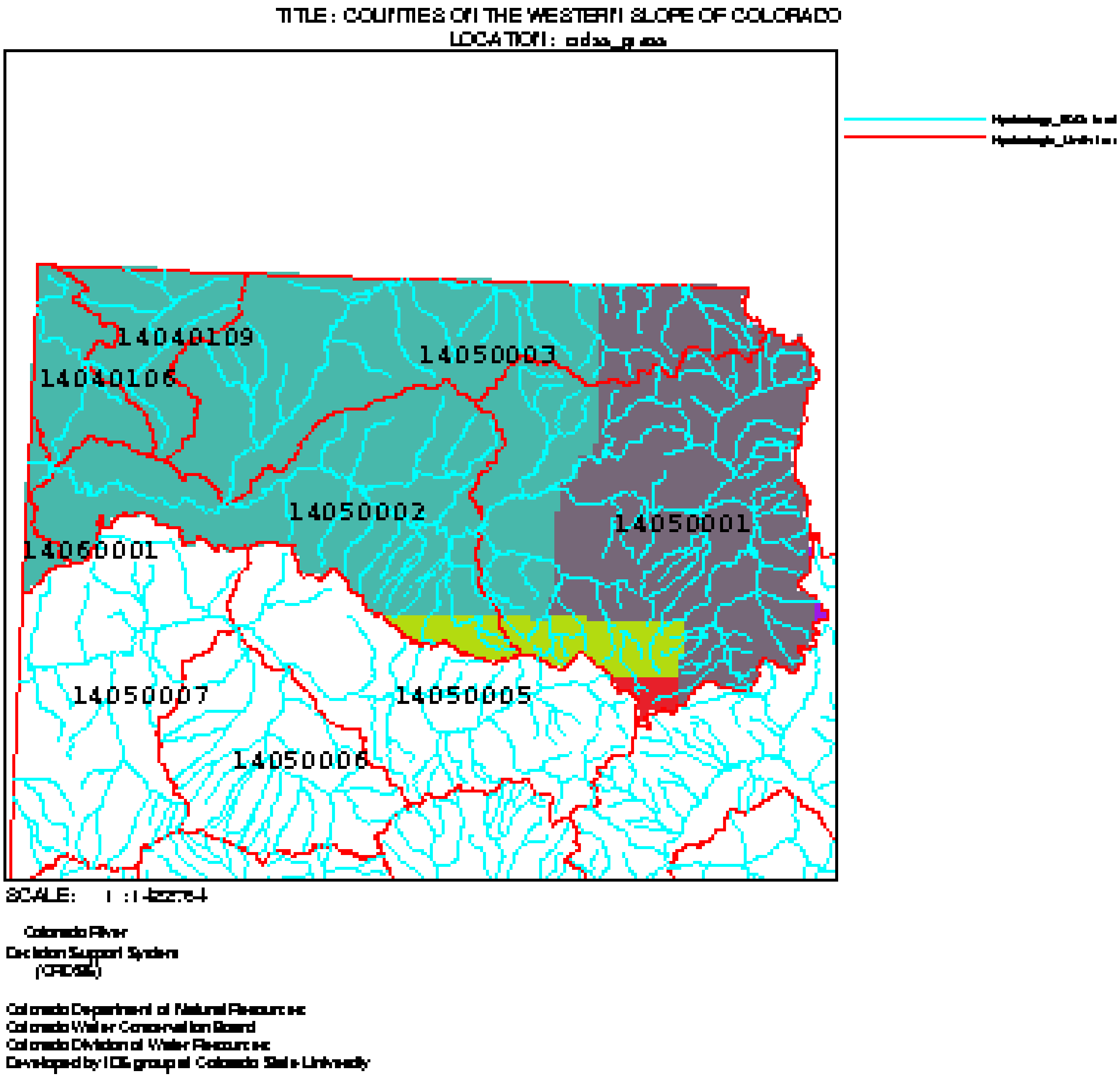
TITLE : COUNTIES ON THE WESTERN SLOPE OF COLORADO
14040109
14040106
14050003
14050002
14050001
14060001
14050007
14050005
14050006
SCALE:
Colorado River
Decision Support System
(CRDSS)
Colorado Department of Natural Resources
Colorado Water Conservation Board
Colorado Division of Water Resources
Developed by IDS group at Colorado State University

EXHIBIT 4

Table 1
M&I Consumption Not Modelled in Phase II

Uses	Basin Wide
Municipal	
Total	1510.5
Phase II	1294.0
Difference	216.5
Industrial	
Total	19542.0
Phase II	17180.0
Difference	2362.0
Total Diff.	**2578.5**

Table 2
Other CU not accounted for in Phase II

Aggregate Node	Percent of Total(3)	Average Annual CU
44_AMY001	28.8	742.6
55_AMY003(1)	0.4	9.8
56_AMY001(2)	0.1	3.0
57_AMY001	18.7	483.1
58_AMY001	52.0	1340.5
Total	100.0	2579.0

1) Water District 54 included in this aggregate node.
2) Not included in Phase III
3) Based on 1998 “Yampa Valley Water Demand Study”

EXHIBIT 5

Sub task 3.10 was completed by following these steps:

1. Go through the list of diversion structures in the Phase II documentation and find all “Other” types of uses. The way to identify them is by looking for acreage set to zero or 999., or efficiency set to 0. or 100. or anything else unusual. Note wdid’s and efficiencies.

2. Run the Phase II model for the historical scenario and get an .xsu report. This reports diversions for each structure and each year, as well as average monthly and annual diversion across the study period by structure. You really want CU, not diversions, but the .xcu report does not have the study period averages.

3. Find the structures in the .xsu report that you identified in Step 1. as having “Other” use. Pull these into a spreadsheet. Enter efficiencies for the structures by hand, and multiply to get CU. If the efficiencies are monthly, calculate the annual CU. [If the.xcu report is changed in future to summarize CU across years for each structure, this step will be unnecessary.]

4. Use the VDB to look at County and HUC, and just get a handle on geographics. This is one way to check on County-HUC of Phase II structures you are unsure of. Print a map (Exhibit 3). Don’t use County-HUC labels because they come out as black bars. Use just HUC or just County.

5. Review the Phase II Consumptive Uses and Losses report. Create spreadsheet that assigns total use to appropriate geographical area (Exhibit 2). Hydrologic unit was selected as basis for three different nodes because of the way data was reported.

6. Once the area represented by each node has been identified, go back to the spreadsheet of Step 3. and group together the Phase II consumptive use by these areas and summarize (Exhibit 1).

7. Create a third spreadsheet that calculates the difference in average annual CU between your Step 5. spreadsheet and your Step 6. spreadsheet, by node (Exhibit 4).

8. Decide where the nodes need to fit into the network, modify the .net file accordingly and run *makenet*.

9. Edit the *commands_dds* file to include setdiv instructions that give each structure a name and set demsrc to 6 in the structure file. **Watright** automatically puts in acreage of -999 and diversion capacity of 999, so those fields don’t need to be changed in the setdiv’s.

10. Edit commands_dds file to include a setdivr to assign and adminstrative number of 1.00000 to all aggregate M&I nodes.

11. Run **watright** with the new *commands_dds*.

12. By hand, create a .stm file of diversions (which are also demands) for each M&I node. It will have exactly the same monthly amounts in each year of the study period. Use an existing .stm file as a template in order to preserve correct format. Put these files in the demandts subdirectory.

When command files for generating the demand files become available, edit them to include -seteff instructions for the aggregated M&I nodes. Efficiencies should all be set to 1.0. Also, edit them to include replace instructions, referencing the .stm files created in Step 12.

TO: File

FROM: Revised by Ray Alvarado 3/99

Roger Sonnichsen & Meg Frantz

SUBJECT: **Sub task 3.11 Yampa River Basin Aggregate Reservoirs and Stock Ponds**

Introduction

This memo describes the approach and results obtained under Sub task 3.11, Aggregate Reservoirs and Stock Ponds. The objective of this task was as follows:

> *Aggregate reservoirs and stock ponds not explicitly modeled in Phase II to allow simulation of effects of minor reservoirs in the basin.*

Approach and Results

Reservoirs and Stock Ponds: Table 1 presents 1) the net absolute storage rights that were modeled in Phase II, 2) net absolute storage rights to be added as aggregated reservoirs in Phase IIIa, and 3) stock ponds to be add as aggregated reservoirs in Phase IIIa. The Phase II reservoir information was obtained from the Phase II reservoir rights file. The absolute decree amount presented in Table 1 for “Total Aggregated Reservoirs” was produced by running **watright** with the -aggres option. The storage presented in Table 1 for “Total Aggregated Stock Ponds” was taken from the year 2 Task Memo 2.09-12, “Consumptive Use Model Non-Irrigation Consumptive Uses and Losses in the Yampa River Basin” (11/19/96).

TABLE 1

Phase	Reservoir	Absolute Decree (AF)	Percent of Total
Phase II	Stillwater Res 1	6,392	4
Phase II	Yamcolo	10,345	6
Phase II	Allen Basin	2,249	1
Phase II	Stagecoach	47,447[1]	27
Phase II	Lake Catamount	11,800	7
Phase II	Fish Creek	1,841	1
Phase II	Steamboat Lake	26,364	15
Phase II	Lester Creek	5,657	3
Phase	Elkhead	13,699	8
Subtotal		125,794	72
Phase IIIa	Total Aggregated Reservoirs	33822	19
Phase IIIa	Total Aggregated Stock Ponds	15958 (capacity)	9
Subtotal		49780	28
Total		175574	100

[1]Conditional decree, but built

Number of Structures and Location: Based on location, the Phase IIIa reservoirs and stock ponds were incorporated into the model as six aggregated structures. Three operational reservoirs were used to model the net absolute decreed storage. Storage was assigned to the three nodes on the basis of water district, as shown in Table 2. Three non-operational reservoirs were used to model the stock ponds; total capacity was partitioned to the three nodes based on USGS hydrologic unit, as reported in Task Memo 2.09-12, and presented in Table 3. The placement of each structure within the model network is shown in Exhibit 1 of Section D.1.

TABLE 2
Operational Reservoirs

ID	WD	Name	Capacity(AF)	%
44_ARY001	57&58	ARY_001_YampaRbelCraig	23,206	69
44_ARY002	44	ARY_002_YampaR@Deerlodge	9,122	27
55_ARY003	54&55	ARY_003_LsnakeRnrLily	1,494	4
		Total:	33,822	100

TABLE 3
Non-Operational Stock Ponds

ID	HUC	Name	Capacity(AF)
44_ASY001	14050001	ASY_001_YampaRbelCraig	8,344
44_ASY002	14050002	ASY_002_YampaR@Deerlodge	4,441
55_ASY003	14050003	ASY_003_LsnakeRnrLily	3,173
		Total:	15,958

Each aggregated reservoir and stock pond was assigned one account and an initial storage equal to their capacity listed above. Each reservoir and stock pond was assumed to be 10 foot deep. Each aggregated reservoir and stock pond was assigned a 2-point area-capacity curve. The first curve point is zero capacity and zero area. The second curve point on the area-capacity table is total capacity with area equal to a total capacity divided by 10. The net evaporation station 10001 as described in Phase II Yampa basin documentation (Section "4.3.2.1 Estimation of Annual Net Evaporation") was assigned to each structure at 100 percent. The Administration of 1 time fill was set to October for each structure. All other parameters were left as the default for each structure.

Target Contents, and End-of-Month Data: Each aggregated reservoir and stock pond was designed to maintain maximum volume, filling to account for evaporation losses. The end-of-month data used in the baseflow calculations was set to the target values.

Water Rights: Water rights associated with each aggregated reservoir and aggregated stock ponds were assigned an administration number equal to 1.00000.

EXHIBIT 1

Sub task 3.11 was completed by executing these steps:

1. Edit *yampa.net* file for the six aggregated reservoirs.

2. Create a *command.res* file that includes the command -aggres and -wrclass, where the -wrclass command is the same as that used in Sub task 3.05. Run **watright** using this *command.res* file.

3. Manually edit the *.res file created in Phase II for the six aggregated reservoirs.

4. Manually edit the *.rer file created in Phase II for the six aggregated reservoirs. Use the *.rag file, output by **watright** under step 2 above, for the breakdown of water rights by administration number. Manually calculate each storage right for each reservoir.

5. Manually edit the *.opr file created in Phase II for the three operational reservoir rules.

6. Use **tstools** to create a *H.tar file. Run **tstools** using a command file that builds the *.tar file from a *zero.del* file and a *.stm file for each reservoir and stock pond in the model. Each *.stm file is a **Statemod** format file.

1. Use **tstools** to create a *.eom file. Run **tstools** using a command file that builds the *.eom file from a *.stm file for each reservoir and stock pond in the model. Each *.stm file is a **Statemod** format file.

Appendix C

1. Green River Basin Plan
Wyoming Depletions in the Little Snake River Basin

2. Yampa River Modeling Assumptions used for Wyoming's Historic, Current and Future Uses on the Little Snake River

TECHNICAL MEMORANDUM

SUBJECT: **Green River Basin Plan**
Wyoming Depletions in the Little Snake River Basin

PREPARED BY: States West Water Resources Corporation

Introduction

The Little Snake River is not directly tributary to the Green River in Wyoming. It is tributary to the Yampa River which ultimately flows into the Green in Dinosaur National Monument in northwestern Colorado. A programmatic biological opinion will be prepared to address the potential effects of the "Management Plan for Recovery of the Endangered Fishes of the Yampa River Basin and Continuation of Existing Human Water Uses and Future Water Development." The purpose of the Management Plan is to allow for the use and future development of Yampa River Valley water resources and to protect and promote the recover of the four endangered fish species which reside in the Upper Colorado River Basin. The development of the Management Plan is occurring as an activity of the ongoing Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin, which has been ongoing since 1988. The State of Wyoming is a participant in the Recovery Program and is participating in the development of the Management Plan. This memorandum documents current estimates of depletions due to activities in Wyoming, and presents estimates of depletions out to year 2045.

The average annual water yield from the Little Snake River Basin in total is 428,000 acre-feet (Hawkins and O'Brien, 1997). Sources of depletions in Wyoming include irrigated agriculture, environmental use, municipal use and transbasin diversions for the City of Cheyenne. As of 1994, total Wyoming depletions in the basin were estimated at 39,900 acre-feet annually (Burns & McDonnell, 1999, Appendix D).

No current depletions are explicitly associated with either industrial or domestic uses. Industrial uses are small and generally included within municipal demand estimates. Domestic uses are also small. To the extent they are comprised of individual small wells serving residential populations, domestic uses will not significantly affect surface water flows.

Therefore, determination of current and future demands consists of updating municipal, agricultural and City of Cheyenne depletions, and projecting them out to year 2045. Additional depletions are estimated for future environmental and industrial uses.

Municipal Depletions

According to Purcell (2000), municipal demands in the Little Snake River Basin are created by uses in the towns of Baggs and Dixon. Between the two, a total of 76 acre-feet of water is currently depleted. Burns and McDonnell (ibid.) provide a higher current municipal depletion of 106.8 acre-feet. Current population estimates are 375, 300 for Baggs and 75 for Dixon, for a current use rate of 0.20 acre-feet/person-year using Purcell's numbers. To project these depletions to year 2045, population projections outlined by Watts (2000a) are used. While Watts proposes three growth scenarios, only the moderate growth scenario is used herein. This scenario is based on U.S. Census Bureau projections.

According to Watts, Baggs and Dixon, together, would experience total growth of 10.8 percent from 2000 to 2030. Projected to 2045, or another 15 years beyond the 2030 horizon looked at by Watts, gives a growth total of 16.2 percent. This projection is performed by linear extrapolation, which is satisfactory in this case because the moderate growth curve is linear in later years.

Therefore, projecting municipal demands consists of taking existing use and increasing it by the expected percentage population increase. A current depletion of 76 acre-feet annually, increased by 16.2 percent, gives a 2045 municipal depletion of 88 acre-feet per year.

City of Cheyenne Depletions

Part of the City of Cheyenne's water supply system is comprised of the Stage I and Stage II Projects. These projects consist of collection and transmission systems in the Little Snake River Drainage. Water is collected from several tributaries of the Little Snake River and delivered to a tunnel that transports the water under the continental divide to Hog Park Reservoir in the North Platte River Basin. Storage in Hog Park Reservoir is released to replace water diverted to Cheyenne through the Rob Roy supply components of the Stage I and II Projects, which transport water from the North Platte River Basin to the South Platte River Basin. The current amount of water diverted from the Little Snake Basin, based on the 1995-1997 usage period, is 14,400 acre-feet per year.

Maximum annual capacity of the Stage I/II system is dictated by the larger of the potential yield of this system (21,000 acre-feet, Black and Veatch, 1994) versus the one-fill limitation on Hog Park Reservoir (22,656 acre-feet). In this case, maximum potential depletion allowed to the Little Snake River Basin is therefore 22,656 acre-feet. The City of Cheyenne has no current plan to enlarge the Stage I/II system, however, its capacity will be reached in the 2040-2050 time frame under current growth estimates.

Agricultural Depletions

Agricultural depletions arise from the consumptive use of water by irrigated crops and pasture. Determination of this depletion requires estimates of the current irrigated acreage in the basin and of actual crop consumptive requirements.

O'Grady, et al, (2000) calculated the amount of irrigated lands in the Little Snake Basin using 1983-1984 aerial photography corrected by 1997-1999 infrared satellite imagery. This work resulted in an estimate of current irrigation of Wyoming lands totaling 15,929 acres. Crop distribution in the basin was previously estimated to be 75 percent grass hay, 11 percent alfalfa and 14 percent irrigated pasture (Western Water Consultants, 1992).

Maximum consumptive use of these crops is only achieved with a full water supply. Consumptive irrigation requirement (CIR) at Dixon, or that amount needed in excess of rainfall to produce a crop, was determined by Trelease et al. (1970), as modified by Pochop, et al. (1992) to be 22.78 inches (1.9 feet) for alfalfa and 20.96 inches (1.75 feet) for pasture grass (or grass hay). Modifications to these numbers to include mountain meadow hay were developed for the Green River Basin Water Plan. For this type of hay, it has been determined that the irrigated lands above Baggs would experience 19.59 inches (1.63 feet) of annual CIR. For purposes of depletion estimation, the following distribution was used: lands above Baggs were represented by 89 percent mountain meadow hay and 11 percent alfalfa, with lands below Baggs represented by 89 percent pasture grass/grass hay and 11 percent alfalfa. From irrigated lands mapping, there exist 11,571 acres above Baggs and 4,358 acres below Baggs.

Under the cropping and irrigated lands percentages given above, the total crop-weighted CIR would be as follows:

Crop	Above Baggs	Below Baggs	Total
Grass Acres	10,298	3,879	14,194
Meadow/Grass CIR, ft.	1.63	1.75	
Grass Total CIR, AF	16,786	6,788	23,574
Alfalfa Acres	1,273	479	1,755
Alfalfa CIR, ft.	1.9	1.9	
Total Alfalfa CIR, AF	2,419	910	3,329
Total CIR, AF	19,205	7,698	26,903

These CIR calculations equate on a crop-weighted basis to 1.66 feet of CIR above Baggs and 1.77 feet below Baggs. Estimates of actual agricultural depletions (and review of irrigation diversion records) have shown less depletion than full CIR would dictate, which is to be expected. Estimates of agricultural depletion, based on studies prepared for High Savery Reservoir (Burns and McDonnell, ibid.), indicate the basin to currently receive about a 75 percent supply without storage. Current agricultural depletions are therefore estimated to be 20,050 acre-feet per year. It is recognized that in practice full CIR is usually not achievable unless fields are flat and irrigation timing is precise. Nonetheless, full CIR values provide a reasonable calculation of the needs and demands of the aggregate irrigation in the basin.

High Savery Dam

Depletions associated with the High Savery Dam project are expected to average 7,724 acre-feet per year as given in the Record of Decision, Final Environmental Impact Statement, Little Snake Supplemental Irrigation Water Supply project (Department of the Army Corps of Engineers, June 5, 2000). Of this amount, approximately 869 acre-feet per year is attributable to evaporation from the reservoir itself, leaving 6,855 acre-feet as the depletion associated with supplemental irrigation practices. This project assumes no additional irrigated acres will be brought under production; it provides supplemental late-season water to existing lands. Adding the 20,050 acre-feet of existing depletion to 6,855 acre-feet due to High Savery provides a total agricultural depletion of 26,905 acre-feet, or essentially a 100 percent water supply based on full CIR. Because High Savery has already had a biological opinion issued, it is included in the environmental baseline under current depletions even though it has yet to be constructed.

Other Projects

In 1995, several dikes were permitted on Muddy Creek by the Little Snake River Conservation District with assistance from several state and federal agencies, including the Wyoming Water Development Commission, the Bureau of Reclamation, and the Bureau of Land Management. These dikes, and the impoundments behind them, are permitted for stock and wetland purposes, and have since been constructed.

According to the reservoir permit maps, the three constructed impoundments have a total surface area of 113.5 acres, resulting in an evaporative depletion of 284 acre-feet per year at a net evaporation rate of 30 inches.

Future Depletions

The projects listed below were developed in large part with input from the Little Snake River Conservation District, and reflect their plans and desired ability to further develop the water resources of the basin.

Environmental Uses

Additional Wetlands Construction

The Little Snake River Conservation District has demonstrated the desire and ability to construct wetland habitat for wildlife, stock and riparian benefits. As quantified earlier, the District in the last 5 years has constructed wetlands with estimated depletions amounting to almost 300 acre-feet per year. Future efforts by the District are anticipated to increase the amount of wetlands by a factor of three, thus creating a future depletion on the order of 1,000 acre-feet.

Little Snake River Basin Small Reservoirs Project

A feasibility report evaluating several small reservoirs in the basin was completed by Lidstone and Anderson in 1998. This report, sponsored by the Little Snake River Conservation District, looked at the feasibility of constructing up to 34 small impoundments for purposes of stock watering, rangeland improvement, and wildlife enhancement. The study resulted in a list of 12 reservoir sites to be considered for Level III design and construction funding. Currently, one reservoir is slated for construction with a second dependent on the availability of funding. For this estimate, the two slated for construction funding are considered as existing depletions, and the remaining ten considered as adding depletions for the 2045 scenario.

The two impoundments under existing funding are Ketchum Buttes 25 and Smiley Draw 27. State Engineer records indicate reservoir surface areas of 10.6 and 8.9 acres, respectively.

Assuming a net evaporation of 30 inches (same as High Savery Dam, considered as representative), the total depletions for these impoundments average 49 acre-feet per year (27 and 22 acre-feet, respectively).

The 10 impoundments for possible future construction are as follows:

Reservoir	Surface Area, ac.	Depletion, acre-feet
Blue Gap 16	50.1	125
Blue Gap 27	14.6	37
Browns Hill 21	2.9	7
Garden Gulch 3	2.8	7
Garden Gulch 32	19.9	50
Ketcham Buttes 34	5.5	14
Peach Orchard Flat 34	88.6	222
Pine Grove Ranch 1	7.7	19
Pole Gulch 27	0.7	2
Riner 28	52.2	131
Total		**614**

Agricultural Uses

Miscellaneous Stock Reservoirs

The Little Snake River Conservation District has indicated that due to siltation and other causes of loss, stock reservoirs are being replaced and will continue to be replaced over the next 45 years. Hundreds of stock reservoirs currently exist in the basin, and at the rate of five per year over 200 new ponds will be constructed by 2045. These new ponds will vary in size, and it is estimated that up to 2,000 acre-feet of depletion will be attributable to their construction and storage.

Dolan Mesa Canal

Currently there is a water right and one enlargement for an irrigation supply project from Savery Creek, the Dolan Mesa Canal. Together, these rights are permitted to serve 1,600 acres. The lands are currently not irrigated, but the possibility exists that current or subsequent owners may try to bring the lands under irrigation. If all 1,600 acres were irrigated, depletion estimates (using 1.66 feet of CIR) would total 2,656 acre-feet.

Willow Creek Storage

Users in the State of Colorado are seeking to implement a storage project on Willow Creek, which flows into the Little Snake River south of Dixon, WY.. The Little Snake River Conservation District has expressed interest in becoming a joint applicant in the project to increase its size and serve lands in Wyoming. Under a Willow Creek reservoir, approximately

1000 acres would be served. The depletion associated with this use would amount to 1,660 acre-feet.

Cottonwood Creek

The Little Snake River Conservation District has indicated that a project is being considered that would have its source of supply water from Cottonwood Creek, tributary to the Little Snake River north of Dixon, WY. The project, anticipated to be brought before the Wyoming Water Development Commission in the fall of 2000, would add 500 acres of irrigation. The depletion associated with this use would amount to 830 acre-feet.

Grieve Reservoir

Grieve Reservoir, which washed out in the summer of 1984, is being considered for rehabilitation and enlargement. This reservoir, if enlarged, is anticipated to serve 300 acres in addition to the original grounds irrigated from the pre-existing structure. The depletion associated with this use would amount to 500 acre-feet.

Muddy Creek

The Muddy Creek Watershed is a candidate for diversions to irrigate up to 1,200 acres of pasture in the lower reaches north of Baggs, WY. At 1.77 feet of consumptive irrigation requirement, this project would result in depletions amounting to 2,100 acre-feet.

Focus Ranch

The Focus Ranch property has a need for supplemental irrigation for 200 acres. The source for this water, likely from storage, is the Roaring Fork near the National Forest boundary. At 0.5 acre-foot per acre supplemental need, this project would result in a depletion of 100 acre-feet.

Pothook – Beaver Ditch

The Little Snake River Conservation District has indicated that a project totaling approximately 400 acres could be brought into production near the confluence of Savery Creek and the Little Snake River. These lands may once have been considered to be served by the Beaver Ditch under an earlier study by the USBR as part of the Savery-Pothook project. At 1.77 feet per acre of consumptive irrigation requirement, this project would result in depletions amounting to 700 acre-feet.

The sum total of projected depletions for the additional agricultural projects listed above is 10,546 acre-feet annually.

Industrial Uses

Industrial use projections outlined by Watts (2000b) are used as a starting point to project future industrial use depletions to year 2045 for the Little Snake River Basin. Watts' industrial use projections do not purport to guess in what areas of the basin industrial use will grow, only that the growth will probably come from established industries. While Watts proposes three growth scenarios, only the moderate growth scenario is used herein (as was done with the projections for municipal use as described above). A reasonable approach given the non-spatial nature of industrial demand projections for the Green River Basin is to assign growth in industrial water demand on an area-weighted basis. To do otherwise would effectively discount that industrial growth will likely occur in the Little Snake River Basin. Wyoming's portion of the Little Snake River drainage (approx. 852,000 acres) is about 6.4 percent of the land area of the portion of the Green River Basin located in Wyoming (approx. 13,349,000 acres) (Chris Jessen, personal communication). Applying this basin area percentage (6.4 percent) to the moderate industrial growth projection of 40,000 acre-feet per year yields 2,560, rounded to 3,000 acre-feet per year, of industrial water demand in year 2045. Application of the high industrial demand projection would yield an estimate of about 6,400 acre-feet per year. Maintaining the State of Wyoming's ability to provide industrial water when demand arises in the next 45 years is critically important. Based on the above, the future depletion estimate includes 3,000 acre-feet per year.

Summary of Current and Future Depletions

The following current depletion estimates are presented:

Current Use	Depletion, AF/YR
Municipal (In-Basin)	76
City of Cheyenne	14,400
Agricultural	20,050
High Savery Reservoir	7,724
Diked Wetlands	284
Small Reservoirs	49
Total	**42,583**

Future depletions (year 2045) are estimated to be:

Future Use	Depletion, AF/YR
Municipal (In-Basin)	88
City of Cheyenne	22,656
Agricultural	20,050
High Savery Reservoir	7,724
Diked Wetlands	1,284
Small Reservoirs	663
Additional Agricultural Uses	10,546

Industrial Use	3,000
Total	**66,011**

For comparison, these depletions are compared to annual flows seen at one gage on the Little Snake River. The gage, Little Snake River near Dixon, WY (9-2570) provides an indication of the annual flows seen in the river. In addition, two tributaries contributing to flow in the river not included in the gage data are Muddy Creek and Willow Creek. Estimates of flows in these tributaries are also provided. Data are taken from USGS reports, which would already reflect depletions.

Gage or Tributary	Average Annual Flow, AF
Little Snake River near Dixon (1911-1971)	372,600
Muddy Creek (1987-1991)	10,690
Willow Creek (1954-1993)	7,440
Total	**408,860**

Summary

These depletions are independent of the amount of water *available* to Wyoming under provisions of the Upper Colorado River Basin Compact and the Colorado River Compact. The State of Wyoming's apportionment of the waters of the Colorado River System exists in perpetuity. Wyoming therefore continues to retain the right to develop all its available water resources under those Compacts in accordance with current governmental permitting requirements.

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DRAFT

M E M O R A N D U M

TO: Yampa River Project Management Team

FROM: Ray Alvarado and John Shields

DATE: October 22, 2001
Revisions Made by the Wyoming State Engineer's Office on November 1, 2001

SUBJECT: Yampa River Modeling Assumptions used for Wyoming's historic, current and future uses on the Little Snake River.

This memorandum addresses the modeling assumptions used in coming up with Wyoming's historic, current and future depletions on the Little Snake River. Information supplied by the Wyoming State Engineer's Office in an August 23, 2000 technical memorandum titled "Green River Basin Plan Wyoming Depletions in the Little Snake River Basin" (note: this memorandum is found in "Appendix B" of the final draft of "A Management Plan for the Yampa River Basin" dated October 2001) as well as data in a spreadsheet provided by the Wyoming State Engineer's Office and labeled "DepletionBreakoutsProject_Wyo.xls" were used.

Historic Conditions

Agriculture

To develop natural flows for the Little Snake, (which are used as the starting point for the CRDSS modeling) Wyoming's historic uses were needed. A total of five nodes were added to the Yampa model to represent agricultural, municipal/industrial uses that are above and below Baggs, Wyoming. Uses by the City of Cheyenne and the High Savery Reservoir were included as separate modeling nodes. The High Savery Reservoir was located on the main stem upstream of Baggs, but is not operated during the historic period. Figure 1 shows the model network diagram that includes the Wyoming nodes. All nodes depicting Wyoming uses are labeled with a 990 prefix. Table 1 lists the model ID for Wyoming's water uses.

Figure 1

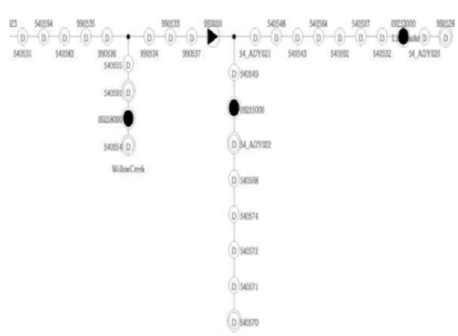


Table 1
Modeling Nodes for Wyoming

Modeling ID	Name
990535	Agricultural Uses below Baggs, Wyo.
990536	M/I Uses below Baggs, Wyo.
990534	Agricultural Uses above Baggs, Wyo.
990533	Agricultural Uses above Baggs, Wyo.
990537	M/I Uses above Baggs, Wyo.
993000	Existing Reservoirs above Baggs, Wyo.
993001	Existing Reservoirs below Baggs, Wyo.
993002	High Savery Reservoir
993003	Diked Wetlands
993004	Stock Ponds
993005	New Ag. Resevoir
990538	New Agricultural Use
990528	City of Cheyenne

A spreadsheet provided by the Wyoming State Engineer's Office, named "DepletionBreakoutsProject_Wyo.xls" was used to estimate annual historic depletion data. This spreadsheet contains the 1971-1995 depletions as determined for the Consumptive Use and Lose Report (CULR) by Wyoming. For the Little Snake, data for CRSS Reach 500; HUC's 14050003 and 14050004 were used. Since only annual depletion amounts were estimated, monthly distributions for the diversions and depletions had to be developed for agricultural and municipal/industrial uses.

For purposes of this analysis, the monthly distributions of the annual values for Wyoming's 1971-1995 agricultural uses were assumed to be distributed based on historic use distribution pattern established for similar uses in Water District 54 in Colorado. Water District 54 borders the Wyoming/Colorado stateline, with the Little Snake River being the main source for irrigators. Agricultural uses upstream of Baggs were modeled as two nodes since the depletions were large. Tables 2 and 3 give the monthly breakdown by year for Wyoming's agricultural nodes that will be modeled to replicate historic use.

Table 2
Wyoming's Estimated Monthly Agriculture Depletions for 990533 & 990534
Above Baggs, Wyo. in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1971	0	0	0	0	0	0	0	253	3778	3676	563	47	8317
1972	40	0	0	0	0	0	34	1640	3606	1489	544	82	7435
1973	18	0	0	0	0	0	1	29	3933	2636	655	56	7327
1974	32	0	0	0	0	0	0	878	3697	2023	1365	856	8850
1975	498	0	0	0	0	0	0	264	2523	2611	807	147	6851
1976	126	0	0	0	0	0	0	1270	1958	1528	618	125	5625
1977	136	0	0	0	0	0	42	1482	1324	497	123	110	3715
1978	12	0	0	0	0	0	0	295	2998	2244	883	294	6726
1979	89	0	0	0	0	0	1	229	2931	2422	894	402	6967
1980	425	0	0	0	0	0	0	39	3278	2112	576	144	6575
1981	39	0	0	0	0	0	0	1497	2520	1781	367	336	6541
1982	184	0	0	0	0	0	0	281	2276	2777	621	49	6188
1983	77	0	0	0	0	0	17	249	3056	2414	746	410	6970
1984	172	0	0	0	0	0	30	654	2110	2206	652	382	6206

1985	242	0	0	0	0	0	0	274	1852	1906	1574	927	6775
1986	1259	0	0	0	0	0	0	1358	2965	2178	1265	689	9714
1987	302	0	0	0	0	0	0	2639	2021	2093	2064	1972	11091
1988	1506	0	0	0	0	0	0	2490	2905	2673	1964	1163	12705
1989	1278	0	0	0	0	0	62	4152	4192	2045	809	518	13056
1990	75	0	0	0	0	0	212	2819	4867	2468	709	865	12015
1991	108	0	0	0	0	0	0	1532	3319	1763	717	617	8056
1992	145	0	0	0	0	0	0	2960	2849	1580	748	442	8725
1993	109	0	0	0	0	0	0	1151	3875	2383	1042	456	9017
1994	147	0	0	0	0	0	539	3324	3242	1806	835	476	10369
1995	177	0	0	0	0	0	40	233	2941	4243	933	486	9051

Table 3
Wyoming's Estimated Monthly Agriculture Depletions for 990535
Below Baggs, Wyo. in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1971	0	0	0	0	0	0	0	62	928	903	138	12	2043
1972	10	0	0	0	0	0	8	403	886	366	134	20	1827
1973	4	0	0	0	0	0	0	7	966	648	161	14	1800
1974	8	0	0	0	0	0	0	216	908	497	335	210	2174
1975	122	0	0	0	0	0	0	65	620	642	198	36	1683
1976	31	0	0	0	0	0	0	312	481	375	152	31	1382
1977	33	0	0	0	0	0	10	364	325	122	30	27	913
1978	3	0	0	0	0	0	0	72	737	551	217	72	1653
1979	22	0	0	0	0	0	0	56	720	595	220	99	1712
1980	104	0	0	0	0	0	0	9	805	519	142	35	1615
1981	10	0	0	0	0	0	0	368	619	437	90	82	1607
1982	45	0	0	0	0	0	0	69	559	682	152	12	1520
1983	19	0	0	0	0	0	4	61	751	593	183	101	1712
1984	42	0	0	0	0	0	7	161	518	542	160	94	1525
1985	60	0	0	0	0	0	0	67	455	468	387	228	1664
1986	319	0	0	0	0	0	0	344	750	551	320	174	2458
1987	74	0	0	0	0	0	0	645	494	512	505	482	2713
1988	371	0	0	0	0	0	0	613	715	658	483	286	3127
1989	311	0	0	0	0	0	15	1011	1021	498	197	126	3180
1990	18	0	0	0	0	0	52	688	1188	602	173	211	2933
1991	26	0	0	0	0	0	0	373	809	430	175	150	1963
1992	35	0	0	0	0	0	0	715	688	382	181	107	2107
1993	27	0	0	0	0	0	0	287	967	595	260	114	2251
1994	35	0	0	0	0	0	130	799	779	434	201	115	2493
1995	44	0	0	0	0	0	10	58	732	1055	232	121	2251

Table 4 presents the average monthly headgate efficiencies used to estimate historic diversions. These values are those established from data collected from Colorado Water District 54, which, as explained above, borders the Wyoming/Colorado Stateline and which has the Little Snake River as the main source of water supply for irrigation uses. These efficiencies were used for the entire 1971-1995 period.

Table 4
Headgate Efficiencies used to Estimate Wyoming's Historical Diversions

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average	9	0	0	0	0	0	19	23	24	35	39	28

Municipal and Industrial

Wyoming's municipal and industrial annual depletions were also taken from the "DepletionBreakoutsProject_Wyo.xls" spreadsheet. Monthly depletions were calculated by dividing the annual value by 12 and then rounding the resultant figure to the nearest whole number. Monthly values were adjusted to get to the annual value when needed. Tables 5 and 6 show the monthly distribution that will be used in the Yampa River Basin model. Monthly diversions were estimated by dividing the monthly depletions shown in Tables 5 and 6 by 30 percent. The rationale for assuming that the municipal and industrial uses only consume 30 percent of the diverted amount is on uses within Colorado.

Table 5
Monthly Depletions for M&I uses above Baggs, Wyo.
Acre-Feet

Water Year	WDID	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1971	990536	2	2	2	2	2	2	2	2	2	2	2	2	24
1972	990536	2	2	2	2	2	2	2	2	2	2	2	2	24
1973	990536	2	2	2	2	2	2	2	3	3	3	3	3	29
1974	990536	3	2	2	2	3	3	3	3	3	3	3	3	33
1975	990536	3	3	3	3	3	3	3	4	4	3	3	3	38
1976	990536	4	3	4	4	4	4	4	4	4	4	4	4	47
1977	990536	5	4	5	5	5	5	5	5	5	5	5	5	59
1978	990536	5	4	4	4	4	5	5	5	5	5	5	5	56
1979	990536	5	4	5	5	5	5	5	5	5	5	5	5	59
1980	990536	5	5	5	5	5	5	5	6	6	6	6	6	65
1981	990536	5	5	5	5	5	5	5	6	5	5	5	5	61
1982	990536	5	5	5	5	5	5	5	6	5	5	5	5	61
1983	990536	5	4	4	4	4	4	4	5	5	5	5	5	54
1984	990536	4	3	4	4	4	4	4	4	4	4	4	4	47
1985	990536	1	1	1	1	1	1	1	1	1	1	1	1	12
1986	990536	1	1	1	1	1	1	1	1	1	1	1	1	12
1987	990536	1	1	1	1	1	1	1	1	1	1	1	1	1
1988	990536	1	1	1	1	1	1	1	1	1	1	1	1	1
1989	990536	1	1	1	1	1	1	1	1	1	1	1	1	1
1990	990536	1	1	1	1	1	1	1	1	1	1	1	1	1
1991	990536	5	4	4	4	4	5	5	5	5	5	5	5	56
1992	990536	7	7	7	7	7	7	7	7	7	7	7	7	84
1993	990536	10	10	10	10	10	10	10	11	11	11	10	10	123
1994	990536	13	13	13	13	13	13	13	14	13	13	13	13	157
1995	990536	17	16	16	17	17	17	17	17	17	17	17	17	202

Table 6
Monthly Depletions for M&I uses below Baggs, Wyo.
Acre-Feet

Water Year	WDID	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1971	990537	4	3	3	3	4	4	4	4	4	4	4	4	45
1972	990537	4	3	3	3	3	4	4	4	4	4	4	4	44
1973	990537	4	4	4	4	4	4	4	5	5	5	5	5	53
1974	990537	5	5	5	5	5	5	5	6	5	5	5	5	61
1975	990537	6	5	5	6	6	6	6	6	6	6	6	6	70
1976	990537	7	7	7	7	7	7	7	8	8	8	7	7	87
1977	990537	9	9	9	9	9	9	9	10	9	9	9	9	109
1978	990537	9	8	8	8	8	8	9	9	9	9	9	9	103
1979	990537	9	9	9	9	9	9	9	10	9	9	9	9	109
1980	990537	10	10	10	10	10	10	10	10	10	10	10	10	120
1981	990537	9	9	9	9	9	9	9	10	10	10	10	10	113
1982	990537	9	9	9	9	9	9	9	10	10	10	10	10	113
1983	990537	8	8	8	8	8	8	8	9	9	9	9	9	101
1984	990537	7	7	7	7	7	7	7	8	8	8	8	7	88
1985	990537	6	6	6	6	6	6	7	7	7	7	7	7	78
1986	990537	6	6	6	6	6	6	7	7	7	7	7	7	78
1987	990537	6	5	5	5	5	5	6	6	6	6	6	6	67
1988	990537	4	3	3	3	4	4	4	4	4	4	4	4	45
1989	990537	3	2	2	3	3	3	3	3	3	3	3	3	34
1990	990537	3	2	2	3	3	3	3	3	3	3	3	3	34
1991	990537	7	6	6	6	6	6	7	7	7	7	7	7	79
1992	990537	11	11	11	11	11	11	11	12	12	12	11	11	135
1993	990537	16	15	16	16	16	16	16	16	16	16	16	16	191
1994	990537	21	20	20	20	20	20	21	21	21	21	21	21	247
1995	990537	24	24	24	24	24	24	24	25	25	25	24	24	291

Reservoir Evaporation

Estimation of the amount of reservoir evaporation that occurred in the Little Snake River Basin was made in the U.S. Bureau of Reclamation's "Consumptive Uses and Losses Report" for 1991-1995. The Wyoming State Engineer's Office segregated the data found in the USBR's Technical Memorandum for the 1991-1995 CULR into the "DepletionBreakoutsProject_Wyo.xls" spreadsheet.

For modeling purposes, two reservoirs will be added to the network that represents aggregated historic reservoir evaporation for above and below Baggs, Wyoming. Table 7 lists the reservoirs that are associated with the modeled reservoirs and the annual evaporation.

Table 7
Historic Reservoir Evaporation
Acre-Feet

Modeled Reservoir	WDID	Structures included	Net Annual Evaporation
Above Baggs, Wyo.	993000	Beavers, Highline, Sheep Mountain	144
Below Baggs, Wyo.	993001	J.O., Little Robber	65
		Total	209

City of Cheyenne

Annual transmountain diversions by the City of Cheyenne were obtained from the Wyoming State Engineer's Office Wyoming for the years 1969-1999. Monthly diversions were estimated by using the 1998 monthly distribution, also obtained from Wyoming. Table 8 gives the monthly diversions that will be used in the Yampa River Basin model. Since the water is exported out of basin, all diversions by Cheyenne will be 100 percent depletive to the Little Snake River.

Table 8
City of Cheyenne Estimated Monthly Diversions
Acre-Feet

Water Year	WDID	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1969	990528	0	0	0	0	0	0	45	3688	4053	403	16	2	8207
1970	990528	0	0	0	0	0	0	44	3575	3928	391	16	2	7955
1971	990528	0	0	0	0	0	0	25	2021	2220	221	9	1	4496
1972	990528	0	0	0	0	0	0	40	3233	3552	353	14	1	7193
1973	990528	0	0	0	0	0	0	45	3651	4012	399	16	2	8124
1974	990528	0	0	0	0	0	0	38	3130	3439	342	14	1	6965
1975	990528	0	0	0	0	0	0	28	2286	2512	250	10	1	5086
1976	990528	0	0	0	0	0	0	42	3426	3765	374	15	2	7624
1977	990528	0	0	0	0	0	0	24	1945	2137	212	8	1	4327
1978	990528	0	0	0	0	0	0	38	3116	3424	340	14	1	6933
1979	990528	0	0	0	0	0	0	45	3690	4055	403	16	2	8211
1980	990528	0	0	0	0	0	0	43	3474	3817	379	15	2	7730
1981	990528	0	0	0	0	0	0	30	2450	2692	268	11	1	5451
1982	990528	0	0	0	0	0	0	53	4306	4731	470	19	2	9581
1983	990528	0	0	0	0	0	0	28	2259	2482	247	10	1	5027
1984	990528	0	0	0	0	0	0	14	1115	1226	122	5	1	2482
1985	990528	0	0	0	0	0	0	54	4408	4843	481	19	2	9807
1986	990528	0	0	0	0	0	0	67	5441	5979	594	24	2	12107
1987	990528	0	0	0	0	0	0	46	3766	4138	411	16	2	8379
1988	990528	0	0	0	0	0	0	39	3166	3478	346	14	1	7044
1989	990528	0	0	0	0	0	0	69	5613	6167	613	24	3	12489
1990	990528	0	0	0	0	0	0	77	6244	6861	682	27	3	13894
1991	990528	0	0	0	0	0	0	91	7398	8129	808	32	3	16462
1992	990528	0	0	0	0	0	0	69	5595	6148	611	24	3	12450

1993	990528	0	0	0	0	0	0	129	10527	11566	1150	46	5	23422
1994	990528	0	0	0	0	0	0	79	6460	7098	706	28	3	14374
1995	990528	0	0	0	0	0	0	67	5458	5997	596	24	2	12144
1996	990528	0	0	0	0	0	0	94	7647	8402	835	33	3	17014
1997	990528	0	0	0	0	0	0	78	6345	6972	693	28	3	14119
1998	990528	0	0	0	0	0	0	82	6683	7343	730	29	3	14870
1999	990528	0	0	0	0	0	0	73	5956	6545	651	26	3	13253

The Colorado's current CRDSS Yampa River Water Resource Planning model incorporated historic depletions at the 100 percent level and is the product of CRDSS Phase IIIb work tasks. Under Task IIIb, the Yampa input data sets were revised to include the 1909 - 1998 water year period. These revisions included new data filling techniques for missing baseflow data (baseflows for the 1909-1974 period were estimated using the USGS Mixed Station linear regression model).

Current Conditions

From technical memorandum "Green River Basin Plan Wyoming Depletions in the Little Snake River Basin", current use listed on page 7 was used for current annual depletions.

Agricultural

Listed on page 7 of the technical memorandum, 20,050 acre-feet is the average depletion under current conditions with an additional 6,855 acre-feet coming from the High Savery Project for a total of 26,905 acre-feet. Table 8 shows how the 26,905 acre-feet of depletions were split between above and below Baggs, Wyoming. Of the 26,905 acre-feet, 23,964 acre-feet are above Baggs, Wyoming and 2,941 acre-feet below. Monthly distribution shown in Table 9 is based on the average distribution derived from Tables 2 and 3. Since the construction of the High Savery Project has not yet been completed, this seems to be a reasonable assumption as to the point of use of the water.

Table 9
Agricultural Depletions under Current Conditions
Acre-Feet

990533	593	0	0	0	0	0	97	2603	3830	2689	1283	887	11982
990534	593	0	0	0	0	0	97	2603	3830	2689	1283	887	11982
990535	146	0	0	0	0	0	23	639	940	660	315	218	2941
Total	1332	0	0	0	0	0	217	5845	8600	6038	2881	1992	26905

Municipal and Industrial

Under current conditions, the 76 acre-feet of depletions occurring due to municipal and industrial uses (as identified in the August 23, 2000 Wyoming Technical Memorandum) are assumed to be distributed on the basis shown in Table 10. The basis of this distribution is, as described above, using the monthly depletions values, dividing the annual value by 12 and then rounding the resultant figure to the nearest whole number.

Table 10
Municipal and Industrial under Current Conditions
Acre-Feet

WDID	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
990536	2	2	2	2	2	2	2	2	2	2	2	2	27
990537	4	4	4	4	4	4	4	4	4	4	4	4	49
Total	6	6	6	6	6	6	6	6	6	6	6	6	76

Reservoir Evaporation

All of Wyoming's agricultural uses modeled will have access to this water. Reservoir evaporation will be based on evaporation rates used for Elkhead Reservoir.

High Savery Reservoir

Yet to be constructed, High Savery Reservoir will provide supplemental irrigation water to the Savery Creek and Little Snake River valleys in the southeastern corner of Wyoming's Green River Basin. Located high on Savery Creek in Carbon County, High Savery will impound over 22,400 AF to provide an annual 12,000 AF yield of supplemental late-season irrigation water. As planned, an earthen dam will impound High Savery. The reservoir will be owned and permitted by the State of Wyoming, and operated by the Savery - Little Snake Water Conservancy District. At full pool, with a storage content of 22,433 AF, the reservoir will have a surface area of 482 acres, (Phil Ogle of the Wyoming Water Development Commission, November 1, 2001).

City of Cheyenne

Current diversions for the City of Cheyenne will be set at 14,400 acre-feet per year and will have a monthly distribution shown in Table 11. The basis for the monthly distribution of the annual amount was estimated by using the 1998 monthly distribution.

Table 11
City of Cheyenne Current Diversions
Acre-Feet

WDID	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
990528	0	0	0	0	0	0	79	6472	7111	707	28	3	14400

Diked Wetlands

In its August 23, 2000 technical memorandum titled "Green River Basin Plan Wyoming Depletions in the Little Snake River Basin" (note: this memorandum is found in "Appendix B" of the final draft of "A Management Plan for the Yampa River Basin" dated October 2001), the Wyoming State Engineer's Office and their consultant stated the following:

"In 1995, several dikes were permitted on Muddy Creek by the Little Snake River Conservation District with assistance from several state and federal agencies, including the Wyoming Water Development Commission, the Bureau of Reclamation, and the Bureau of Land Management. These dikes, and the impoundments behind them, are permitted for stock and wetland purposes, and have since been constructed. According to the reservoir permit maps, the three constructed impoundments have a total surface area of 113.5 acres, resulting in an evaporative depletion of

284 acre-feet per year at a net evaporation rate of 30 inches." For modeling purposes, a reservoir node will be included to represent the three dikes.

Small Reservoirs

Current stock reservoir depletion was estimated in the August 23, 2000 memorandum by the Wyoming State Engineer's Office and their consultant as amounting to 49 acre-feet per year. The assumed distribution of the evaporation from these miscellaneous reservoirs (which will be modeled as one aggregate reservoir) will be the same as that determined by the State of Colorado for Colorado Water District No. 54.

Future Conditions (2045)

Agricultural

The existing depletions used for "current conditions", 26,950 acre-feet will continued to be used under future conditions. An additional 5,200 acres is anticipated coming online in the future and will be supplied by reservoirs. For modeling purposes, the 5,200 acres will be modeled as one node with it supply coming from a single reservoir. Table 12 lists the structure and proposed acreage and estimated depletion that will be modeled as a single structure.

Table 12
Future Agricultural

Name	Acreage	Estimated Depletion, af
Dolan Mesa Canal	1,600	2,656
Willow Creek Storage	1,000	1,660
Cottonwood Creek	500	830
Grieve Reservoir	300	500
Muddy Creek	1,200	2,100
Focus Ranch	200	100
Pothook-Beaver Ditch	400	700
Total	5,200	8,546

Municipal and Industrial

For future conditions the 88 acre-feet of municipal depletions was combined with the 3,000 acre-feet for industrial for a combined total of 3,088 acre-feet shown in Table 13.

Table 13
Municipal and Industrial under Current Conditions
Acre-Feet

WDID	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
990536	91	91	91	91	91	91	91	92	92	92	92	92	1097
990537	166	165	166	166	166	166	166	166	166	166	166	166	1991
Total	257	256	257	257	257	257	257	258	258	258	258	258	3088

City of Cheyenne

Future diversions for the City of Cheyenne will be set at 22,656 acre-feet per year and will have a monthly distribution shown in Table 14. The assumed monthly distribution of the diversions will be the same as that used/assumed for the current diversions. This assumption is made on the basis that the future use of water by Cheyenne is likely to be for the same uses in the same months of the year when the population of Cheyenne is larger in the future and seems reasonable for purposes of this analysis.

Table 14
City of Cheyenne Current Diversions
Acre-Feet

WDID	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
990528	0	0	0	0	0	0	125	10182	11188	1112	44	5	22656

Diked Wetlands

For purposes of this analysis, an additional 1,000 acre-feet of additional wetland depletions will be added to diked wetland model node.

Small Reservoirs

Depletions due to small reservoirs will increase by 614 acre-feet according to the August 23, 2000 technical memorandum titled "Green River Basin Plan Wyoming Depletions in the Little Snake River Basin". An additional 2,000 acre-feet will be modeled to account for miscellaneous additional stock reservoirs.

Since these reservoirs will most likely have as their purposes and water uses stock watering, rangeland improvement and wildlife enhancement, for purposes of this analysis the assumption was made that the depletion will be handled as reservoir evaporation. That evaporation is assumed to have the same monthly distribution as assumed for reservoir evaporation occurring in Colorado Water District 54, which, as explained above, borders the Wyoming/Colorado Stateline.

CRDSS_Wyo_depletions_2001.doc

Appendix D

Calibration Results with Calculated Irrigation Demand

Note: This Appendix describes a Calculated Data Set that was completed in 2004. The Yampa River Model Historical (calibration), Baseline, and Calculated data files were updated in October 2009, and the 2009 calibration and Baseline data sets are described in the main body of this user manual. Inconsistencies between the 2004 and 2009 data sets include:

1) maximum irrigation efficiency set to 0.60 in 2004, and set to 0.54 in 2009
2) differences in IWR for fields below 6,500 ft in elevation, because an elevation adjustment was applied to crop coefficients in the Blaney-Criddle analysis in the 2009 model
3) adjustments to the storage rights and accounts in Yamcolo and Stagecoach Reservoirs, and enlargement of Elkhead Creek Reservoir.

The approach described for the Calculated Data Set is generally accurate. Table values in this appendix are similar to, but not exactly, what is produced by the 2009 Calculated Data Set.

Calculated Data Set

The "Calculated Data Set" is a data set that was created to further look at calibration of the Yampa River basin model. The unique characteristic of this data set is the demand file. Demand for irrigation users in this scenario is estimated outside the model, based on crop consumptive use and historical efficiency. The scenario is historical in the sense that it uses historical operating rules, and reservoirs come on-line when they did historically, but the irrigation demand is not strictly historical. In the calibration run, demand was set to historical diversions, so that it reflects an irrigator's operational decisions or circumstances that are unrelated to use by crops. For example, if a headgate was damaged in spring flooding and didn't become usable until several weeks into the normal irrigation season, that would be reflected in the calibration data set. Demand in the Calculated data set reflects the theoretical crop needs, that is, the amount that should be diverted if the crop is to acquire a full supply.

Because demand in the Calculated Data Set is not tightly tied to actual diversions, results from a historical run with the Calculated Data Set tend to deviate from observed values a little more than the calibration run. On the other hand, the run provides insight into historical needs and shortages that the calibration run does not provide. This is because the calibration run assumes there is no crop demand above the historically diverted amount, when in fact, supply (or the means to supply) may have been limiting.

Calculated Demand

Calculated demand is computed by demandts based on time series of historical diversions and crop irrigation water requirement. Based on a period specified by the user, the DMI computes an average efficiency for each structure, for each month of the year. Efficiencies in the sample for which the monthly average is derived are computed as the monthly irrigation crop water requirement divided by the month's diversion amount.

For some structures, the average monthly efficiency computed this way exceeded 60 percent, typically in July, August, or September. It was assumed when this occurred that the crop was supply limited. For the purpose of developing a theoretical monthly diversion demand, the average monthly efficiency was not allowed to exceed 60 percent. Demand was then estimated in each month as the irrigation crop water requirement, divided by the average monthly efficiency (constrained to 60 percent).

Since historical diversions tend to be available in the database back to 1975 for the Yampa basin, the period used for developing irrigation efficiency was 1975 through 1998. Demandts calculated a theoretical diversion demand for each month within this time frame based on the particular month's crop water requirement and average efficiency. Outside that period, Calculated demand was filled using the standard time series filling method described in Section 4.

Basinwide Calculated demand over the calibration period (1975-2000) amounts to 518,000 af/yr on average. This compares with historical diversions which averaged 500,000 af/yr over the same period.

Calculated Data Set Calibration Results

Calibration of the Yampa River model is considered very good, with most streamflow gages deviating less than one percent from historical values on an average annual basis. More than half the diversion structures' shortages are at or below 1 percent on an annual basis, and the basinwide shortage is 2 percent per year, on average. Simulated reservoir contents are representative of historical values.

Water Balance

Table D.1 summarizes the water balance for the Yampa River model, for the calibration period (1975-2000). Following are observations based on the summary table:

- Surface water inflow to the basin averages 2.12 million acre-feet per year, and surface water outflow averages 1.93 million acre-feet per year.
- Annual diversions amount to approximately 500,000 acre-feet on average.
- Approximately 156,000 acre-feet per year is consumed.
- The column labeled "Inflow – Outflow" represents the net result of gain (inflow, return flows, and negative change in reservoir and soil moisture contents) less outflow terms (diversions, outflow, evaporation, and positive changes in storage). The small values are due to rounding on a monthly basis and indicate that the model correctly conserves mass.

Streamflow Calibration Results

Table D.2 summarizes the annual average streamflow for water years 1975 through 2000, as estimated using the Calculated data set. It also shows average annual values of actual gage records for comparison. Both numbers are based only on years for which gage data are complete. Differences between gaged and simulated average annual streamflows are within 1 percent. The Stagecoach gage is affected by Stagecoach Reservoir, whose hydropower operations are not perfectly modeled. Figures D.1 through D.6 (at the end of this appendix) graphically present monthly streamflow estimated by the model compared to historical observations at key streamgages. When only one line appears on a graph it indicates that the simulated and historical results are the same at the scale presented.

Table D.1
Average Annual Water Balance for Calculated Data Set Calibration, Yampa River Model (af/yr)

Month	Inflow	Return	From Soil Moisture	Total Inflow	Diversions	Resvr Evap	Stream Outflow	Resvr Change	To Soil Moisture	Soil Moisture Change	Total Outflow	Inflow - Outflow	CU
OCT	40,099	21,760	88	61,947	23,924	777	36,816	341	233	-144	61,947	0	4,904
NOV	33,743	8,320	0	42,063	3,178	-26	37,688	1,222	0	0	42,063	0	1,369
DEC	28,108	5,767	0	33,875	3,453	-281	30,173	530	0	0	33,875	0	1,462
JAN	27,442	4,699	0	32,141	3,471	-288	28,749	209	0	0	32,141	0	1,494
FEB	33,550	3,616	0	37,165	3,134	-60	33,824	266	0	0	37,165	0	1,369
MAR	84,686	2,983	0	87,668	3,434	365	83,166	703	0	0	87,668	0	1,799
APR	242,449	6,451	30	248,930	11,401	915	234,496	2,088	254	-223	248,930	0	4,144
MAY	658,909	41,926	50	700,885	79,239	1,718	618,436	1,441	1,313	-1,263	700,885	0	20,463
JUN	659,730	89,553	235	749,518	156,052	2,457	591,597	-823	555	-321	749,517	1	38,172
JUL	219,619	73,726	1,054	294,399	117,506	2,382	175,544	-2,087	52	1,002	294,399	0	36,770
AUG	58,160	38,206	1,653	98,019	59,138	1,762	36,377	-911	84	1,569	98,019	0	28,714
SEP	35,479	26,023	737	62,239	35,998	1,517	24,720	-733	104	633	62,239	0	15,309
AVG	2,121,973	323,029	3,848	2,448,848	499,929	11,239	1,931,586	2,246	2,594	1,254	2,448,848	1	155,970

Note: Consumptive Use (CU) = Diversion (Divert) * Efficiency + Reservoir Evaporation (Evap)

Table D.2
Historical and Simulated Average Annual Streamflow Volumes (1975-2000)
Calculated Data Set (acre-feet/year)

Gage ID	Historical	Simulated	Historical minus Simulated		Gage Name
			Volume	Percent	
9236000	29,633	29,617	16	0	Bear River Near Toponas
9237500	62,434	62,810	-376	-1	Yampa River Below Stagecoach Reservoir
9238900	46,263	46,421	-158	0	Fish Creek At Upper Station
9239500	332,908	333,108	-201	0	Yampa River At Steamboat Springs
9241000	231,396	231,445	-49	0	Elk River At Clark
9244410	834,379	835,282	-902	0	Yampa River Below Diversion near Hayden
9245000	42,324	42,324	0	0	Elkhead Creek Near Elkhead
9245500	*No gage, 1975 - 2000*			0	North Fork Elkhead Creek
9246920	7,957	8,000	-42	-1	Fortification Creek near Fortification
9247600	940,736	937,988	2,749	0	Yampa River Below Craig
9249000	*No gage, 1975 - 2000*			0	East Fork Of Williams Fork
9249200	28,073	28,066	7	0	South Fork Of Williams Fork
9249750	157,476	157,324	153	0	Williams Fork At Mouth
9251000	1,170,876	1,165,949	4,926	0	Yampa River Near Maybell
9253000	172,333	171,692	641	0	Little Snake River Near Slater
9255000	63,087	63,196	-109	0	Slater Fork Near Slater
9258000	7,930	7,865	65	1	Willow Creek Near Dixon
9260000	427,024	423,941	3082	1	Little Snake River Near Lily
9260050	1,629,816	1,620,112	9,704	1	Yampa River At Deerlodge Park

Diversion Calibration Results

Table D.3 summarizes the difference between average annual historical diversions and average annual simulated diversions for water years 1975 through 2000, for each ditch. Where the difference is negative, the Calculated demand was larger than historical diversions, and the model shows that the higher level of demand could have been met. Note that the differences in this table reflect both modeling error and differences between the Calculated demand and actual diversions.

Table D.3
Historical and Simulated Average Annual Diversions (1975-2000)

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
440509	1,044	1,120	-76	-7	Wilson Ditch
440511	2,570	2,787	-217	-8	Wisconsin Ditch
440514	574	612	-39	-7	Wooley & Johnson D
440517	1,086	1,553	-467	-43	Yampa Val Stock Br Co D
440518	282	229	53	19	Yellow Jacket Ditch No 1
440519	186	185	1	1	Yellow Jacket Ditch No 2
440522	10,915	10,915	0	0	Craig Station D & Pl
440524	223	209	14	6	Aq Ditch 1
440527	554	589	-35	-6	Air Line Irr D
440533	233	176	57	25	Anderson Ditch
440538	205	110	95	46	Averill Ditch
440541	840	793	48	6	Bailey Ditch
440570	1,212	1,239	-27	-2	Card Ditch
440572	170	75	96	56	Carrigan-Averill D
440573	816	589	227	28	Cataract Ditch
440581	1,703	1,703	0	0	Craig Water Supply Pl
440583	2,944	2,850	94	3	Cross Mtn Pump - Grounds
440584	2,511	5,367	-2,855	-114	Cross Mtn Pump No 1 & 2
440585	414	438	-23	-6	Crystal Ck Ditch
440586	1,916	2,466	-494	-26	D D & E Ditch
440587	1,352	1,588	-236	-17	D D Ferguson D No 2
440589	5,875	5,745	131	2	Deep Cut Irr D
440590	1,389	927	462	33	Deer Ck & Morapos D
440593	331	244	87	26	Dennison & Martin D
440601	762	800	-38	-5	Dunston Ditch
440607	3,022	2,269	752	25	Egry Mesa Ditch
440611	935	310	625	67	Elk Trail Ditch
440612	685	450	236	34	Elkhorn Irr Ditch
440613	259	453	-195	-75	Ellgen Ditch
440614	285	229	56	20	Ellis & Kitchens D

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
440628	356	281	75	21	Gibbons Wilson Jordan D
440635	410	401	8	2	Grieser Ditch
440638	282	200	82	29	Hadden Base Ditch
440644	307	521	-214	-70	Harper Ditch 1
440645	276	266	10	4	Harper Ditch 2
440647	760	616	144	19	Haughey Irr Ditch
440650	66	253	-187	-283	Highline Mesa Baker D
440651	1,504	1,730	-226	-15	Highland Ditch
440652	770	743	27	4	Highland Aka Highline D
440660	348	359	-12	-3	J A Martin Ditch
440661	446	459	-13	-3	J P Morin Ditch
440670	240	315	-75	-31	J W Kellogg D 2
440675	3,428	3,644	-215	-6	Juniper Mtn Tunnel
440677	2,015	2,091	-76	-4	K Diamond Ditch
440681	290	245	46	16	Lamb Irr Ditch
440687	2,630	2,642	-11	0	Lily Park Pump No 1
440688	1,641	1,398	243	15	Little Bear Ditch
440691	1,041	954	87	8	M Ditch
440692	1,998	1,858	140	7	Martin Ck Ditch
440694	14,742	14,683	58	0	Maybell Canal
440695	233	233	0	0	Maybell Mill Pipeline
440698	334	288	46	14	Mcdonald Ditch
440699	779	888	-109	-14	Mckinlay Ditch No 1
440700	1,345	1,397	-52	-4	Mckinlay Ditch No 2
440702	2,125	2,105	20	1	Mcintyre Ditch
440706	719	924	-205	-28	Milk Ck Ditch
440711	930	935	-5	-1	Mock Ditch
440716	178	327	-148	-83	Mullen Ditch
440723	907	925	-18	-2	Nichols Ditch No 1
440724	1,878	1,920	-42	-2	Norvell Ditch
440729	2,022	1,972	50	2	Patrick Sweeney D
440731	1,055	1,009	45	4	Peck Irrig D
440735	679	582	98	14	Pine Ck Ditch
440740	608	599	8	1	Ratcliff Ditch
440747	185	143	42	23	Roby D Aka Roby D No 1

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
440748	202	161	40	20	Roby Ditch No 2
440749	227	241	-13	-6	Round Bottom D No 1
440750	281	286	-4	-2	Round Bottom D No 2
440751	641	656	-15	-2	Round Bottom Ditch
440763	1,147	1,219	-72	-6	Smith Ditch
440765	819	817	2	0	South Side Ditch
440770	231	216	16	7	Starr Irrig Ditch
440778	1,670	1,661	9	1	Sunbeam Ditch
440785	724	732	-9	-1	Tipton Irr Ditch
440786	1,637	1,705	-68	-4	Tisdel D No 2
440790	962	977	-14	-1	Utley Ditch
440801	1,229	1,247	-18	-1	Cross Mtn Pump - Guess
440806	260	312	-53	-20	Ellgen No 2 Ditch
440812	316	175	141	45	Hart Ditch
440814	524	550	-25	-5	Highline Ditch
440820	1,226	1,209	18	1	Lowry Seeley Pump
440821	319	383	-64	-20	Mack Ditch
440828	434	427	7	2	Mock Ditch No 3
440830	1,475	1,479	-4	0	Old Sweeney Ditch
440863	1,632	1,655	-23	-1	Henry Sweeney Ditch
440998	381	360	21	6	Dry Cottonwood Ditch
441122	1,412	750	651	46	Vaughn Pump
442214	345	439	-95	-27	Wise Ditch Alt Pt
540507	1,062	988	73	7	Beeler Ditch
540531	2,389	2,925	-536	-22	Heeley Ditch
540532	1,166	1,054	112	10	Home Supply Ditch
540543	921	849	73	8	Luchinger Ditch
540548	1,360	1,095	264	19	Morgan & Beeler D
540549	734	939	-204	-28	Morgan Slater Ditch
540554	440	617	-177	-40	Perkins Fox Ditch
540555	992	1,269	-277	-28	Perkins Irr Ditch
540564	616	584	32	5	Salisbury Ditch
540568	890	879	12	1	Slater Fork Ditch
540570	570	629	-59	-10	Slater Park Ditch No 1
540571	301	225	76	25	Slater Park Ditch No 2

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
540572	321	203	117	37	Slater Park Ditch No 3
540574	601	449	153	25	Slater Park Ditch No 5
540583	3,752	3,453	298	8	Trowel Ditch
540591	2,009	2,111	-102	-5	Willow Ck Ditch
540592	399	383	16	4	Wilson Ditch
540594	765	1,082	-317	-41	Woodbury Ditch
550504	843	843	0	0	Escalanta Pump 2
550506	2,078	2,090	-12	-1	Majors Pump No 2
550507	946	943	3	0	Nine Mile Irr Ditch
550508	765	769	-4	-1	Nine Mile Irr Pl
550513	699	689	10	1	Visintainer Ditch
550519	666	679	-13	-2	Rinker Pump D
550537	1,528	1,520	8	1	Lefevre No 1 Pump
570508	2,221	2,045	176	8	Brock Ditch
570510	3,335	3,135	201	6	Cary Ditch Co Ditch
570512	4,783	4,783	0	0	Colo Utilities D & Pl
570513	332	364	-32	-10	Connell Ditch
570517	703	701	1	0	David M Chapman Ditch
570519	944	1,029	-85	-9	Dennis & Blewitt D
570524	470	521	-52	-11	East Side Ditch
570525	587	859	-272	-46	East Side Ditch 2
570535	468	485	-17	-4	Erwin Irrigating Ditch
570539	7,315	7,404	-90	-1	Gibraltar Ditch
570544	972	935	37	4	Highland Ditch
570545	1,005	1,067	-62	-6	Homestead Ditch
570555	875	859	16	2	Last Chance Ditch
570561	484	476	9	2	Male Moore Co Ditch
570563	3,933	3,938	-9	0	Marshall Roberts Ditch
570576	523	562	-40	-8	Orno Ditch
570579	836	896	-60	-7	R E Clark Ditch
570584	602	623	-22	-4	Saddle Mountain Ditch
570592	7,420	7,091	329	4	Shelton Ditch
570608	896	892	4	0	Trout Creek Ditch 3
570609	319	325	-6	-2	Trout Creek Ditch 2
570611	5,571	5,304	268	5	Walker Irrig Ditch

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
570622	2,586	2,541	45	2	Williams Irrig Ditch
570623	714	864	-150	-21	Williams Park Ditch
570635	1,009	1,023	-14	-1	Koll Ditch
574629	1,456	1,456	0	0	Rich Ditch
580500	1,737	1,632	105	6	Acton D
580506	266	386	-120	-45	Allen Basin Supply D
580508	1,065	1,043	21	2	Alpha Ditch
580530	2,087	2,213	-127	-6	Baxter Ditch
580532	357	369	-12	-3	Beaver Creek D
580539	4,349	4,124	224	5	Big Mesa Ditch
580541	1,670	1,678	-8	0	Bird Ditch
580549	305	556	-251	-82	Borland Vail Ditch
580556	321	283	38	12	Brinker Creek Ditch
580559	644	650	-6	-1	Brooks Ditch
580561	371	389	-18	-5	Brumback Ditch
580564	2,349	2,528	-179	-8	Buckingham Mandall D
580568	1,361	1,356	4	0	Burnett Ditch
580569	275	284	-9	-3	Burnt Mesa D
580574	288	318	-30	-10	C R Brown Moffat Coal D
580577	1,130	1,073	57	5	Campbell Ditch
580582	458	424	33	7	Charles & A Leighton D
580583	222	248	-26	-12	Charles H Kemmer D
580588	654	646	9	1	Clark & Burke Ditch
580589	489	453	36	7	Coal Creek Ditch
580590	138	270	-132	-95	Coleman Ditch
580591	823	834	-11	-1	Collins Ditch
580599	806	826	-21	-3	Cullen Ditch 2
580604	176	309	-133	-76	Day Ditch
580612	518	553	-35	-7	Dever D
580618	1,745	1,623	122	7	Duquette Ditch
580622	1,556	1,564	-7	0	Egeria Ditch
580623	1,105	1,132	-28	-2	Ekhart Ditch
580626	2,576	2,600	-24	-1	Elk Valley Ditch Co. D.
580627	2,366	2,002	365	15	Enterprise Ditch
580628	336	349	-13	-4	Excelsior Ditch

WD ID	Historical	Simulated	Historical minus Simulated Volume	Percent	Structure Name
580633	1,224	1,068	156	13	Felix Borghi Ditch
580634	905	884	21	2	Ferguson Ditch
580640	487	499	-12	-3	First Chance Ditch
580642	2,082	2,082	0	0	Fish Cr Mun Water Intake
580643	1,504	1,585	-82	-5	Fix Ditch
580649	1,746	1,682	65	4	Franz Ditch
580662	1,835	1,570	264	14	Graham & Bennett D
580663	506	442	64	13	Greer Ditch
580665	279	285	-7	-2	Guido Ditch
580684	1,050	943	107	10	Hernage & Kolbe Ditch
580685	366	446	-80	-22	High Mesa Irr D
580687	357	369	-12	-3	Highline Beaver Ditch
580694	2,206	2,203	3	0	Hoover Jacques Ditch
580695	691	558	133	19	Hot Spgs Cr Highline D
580714	2,163	2,062	101	5	Keller Ditch
580717	1,074	993	81	8	Kinney Ditch
580721	482	465	17	4	L L Wilson D
580722	387	433	-46	-12	Lafon Ditch
580728	610	632	-22	-4	Larson Ditch
580730	601	741	-140	-23	Lateral A Ditch
580731	274	315	-42	-15	Laughlin Ditch
580738	1,279	1,500	-221	-17	Lindsey Ditch
580749	500	552	-52	-10	Lower Pleasant Valley D
580756	435	441	-6	-1	Lyon Ditch 2
580763	4,598	4,438	160	3	Mandall Ditch
580767	376	379	-3	-1	Mayflower Ditch
580777	491	428	63	13	Mill Ditch 1
580782	267	247	20	8	Moody Ditch
580783	2,807	2,610	197	7	Morin Ditch
580791	311	293	18	6	Muddy Ditch 1
580798	900	995	-95	-11	Nickell Ditch
580801	321	374	-53	-16	North Hunt Creek Ditch
580805	716	725	-10	-1	Oak Creek Ditch
580807	562	589	-27	-5	Oak Dale Ditch
580808	1,027	1,117	-89	-9	Oakton Ditch

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
580809	214	258	-44	-20	Old Cabin Ditch
580811	241	259	-18	-8	Oligarchy Ditch
580813	477	502	-25	-5	Palisade Ditch
580821	1,549	1,507	42	3	Pennsylvania Ditch
580826	331	324	7	2	Pony Creek D
580830	227	200	27	12	Priest Ditch
580844	398	436	-38	-10	Sage Hen Ditch
580847	308	389	-82	-27	Sand Creek Ditch
580863	1,851	2,004	-154	-8	Simon Ditch
580866	722	731	-9	-1	Snow Bank Ditch
580868	1,969	1,605	364	18	Soda Creek Ditch
580872	658	667	-10	-1	South Side Ditch
580879	2,402	2,376	27	1	Stafford Ditch
580895	966	897	70	7	Sunnyside Ditch 1
580897	2,698	2,646	52	2	Suttle Ditch
580908	434	465	-31	-7	Trull Morin Ditch
580914	1,538	986	552	36	Union Ditch
580915	1,040	1,011	29	3	Upper Elk River D Co. D
580916	1,145	1,248	-102	-9	Upper Pleasant Valley D
580917	434	507	-73	-17	Vail Savage Ditch
580920	9,806	7,772	2,034	21	Walton Creek Ditch
580922	582	585	-3	0	Weiskopf Ditch
580924	239	241	-2	-1	Welch & Monson D
580928	456	491	-35	-8	Wheeler Bros Ditch
580933	542	529	13	2	Whipple Ditch
580939	402	434	-32	-8	Windsor Ditch
580943	226	552	-325	-144	Woodchuck D Soda Ck Hg
580944	2,120	2,096	24	1	Woolery Ditch
580945	1,155	1,177	-22	-2	Wooley Ditch
580980	456	447	9	2	Gabioud Ditch
581021	868	888	-20	-2	Lee Irrigation D
581035	560	568	-7	-1	North Side Ditch
581074	472	472	0	0	Rossi Highline Ditch
581085	481	602	-121	-25	Mill Creek Ditch
581583	22,301	22,301	0	0	Stagecoach Hydroelectric

WD ID	Historical	Simulated	Historical minus Simulated Volume	Historical minus Simulated Percent	Structure Name
582374	199	199	0	0	Steamboat Ski Snow Pl
584630	304	231	73	24	Dome_Creek_Ditch
584684	801	794	8	1	Sarvis Ditch
584685	4,620	4,256	364	8	Stillwater Ditch
584686	1,795	1,600	196	11	Stillwater_Colo
990528	10,552	10,552	0	0	Cheyenne_City
990533	31,879	31,749	130	0	Wyoming_Irrig1
990534	31,879	31,403	476	1	Wyoming_Irrig2
990535	7,837	7,837	0	0	Wyoming_Irrig3
990536	187	187	0	0	Wyoming_M&I2
990537	353	344	8	2	Wyoming_M&I
990538	0	0	0	0	New_Wyo_Ag
44_ADY012	921	1,108	-188	-20	ADY012_Elkheadcreek
44_ADY013	1,742	2,857	-1,115	-64	ADY013_Yamparbelcraig
44_ADY014	4,359	4,748	-389	-9	ADY014_Efkwilliamsfork
44_ADY015	3,530	3,674	-144	-4	ADY015_Sfkwilliamsfork
44_ADY016	3,490	3,673	-183	-5	ADY016_Williamsfork
44_ADY017	572	689	-117	-21	ADY017_Milkcrabvgspring
44_ADY018	1,936	2,787	-851	-44	ADY018_Milkcreek
44_ADY019	2,124	2,267	-143	-7	ADY019_Yamparnrmaybell
44_ADY025	3,358	3,290	69	2	ADY025_Yampar@Deerlodge
44_AMY001	742	742	0	0	44_AMY001_Yamparbelcraig
44_FDP001	0	0	0	0	44_Fdp_Wd_44
44_WSA	0	0	0	0	44_WSA_Edfdemand
54_ADY020	2,422	2,813	-391	-16	ADY020_Lsnakernrslater
54_ADY021	3,112	3,039	73	2	ADY021_Lsnakerabvslater
54_ADY022	6,478	5,545	934	14	ADY022_Slatercreek
54_ADY023	17,677	17,533	143	1	ADY023_Lsnakeabvdryglch
55_ADY024	2,045	2,015	30	1	ADY024_Lsnakernrlily
55_ADY026	211	216	-5	-3	ADY026_Yampar@Greenr
55_AMY003	13	13	0	0	55_AMY003_Lsnakernrlily
55_FDP001	0	0	0	0	Fu_Dev_55
56_ADY027	6,940	6,716	224	3	ADY027_Greenriver
56_FDP001	0	0	0	0	Fu_Dev_56
57_ADY009	2,236	2,284	-48	-2	ADY009_Troutcreek

WD ID	Historical	Simulated	Historical minus Simulated Volume	Historical minus Simulated Percent	Structure Name
57_ADY010	590	526	64	11	ADY010_Yamparnrhayden
57_ADY011	1,201	1,285	-83	-7	ADY011_Yamparabvelkhead
57_AMY001	484	484	0	0	57_AMY001_Yamparabcraig
57_FDP001	0	0	0	0	Fu_Dev_57
57_NAG01	0	0	0	0	Nu_Ag_Dev
57_NMID01	0	0	0	0	Nu_Fu_M&I
57_NPWR01	0	0	0	0	Nu_Fu_Pwr
58_ADY001	2,154	2,130	23	1	ADY001_Upperbearriver
58_ADY002	4,063	3,966	97	2	ADY002_Chimneycreek
58_ADY003	4,479	4,490	-12	0	ADY003_Bearrabvhuntck
58_ADY004	2,902	2,962	-60	-2	ADY004_Bearrabvstagecoa
58_ADY005	4,247	4,583	-336	-8	ADY005_Yamparabvsteambt
58_ADY006	1,454	1,559	-105	-7	ADY006_Elkrivernrclark
58_ADY007	1,968	2,367	-399	-20	ADY007_Middleelkriver
58_ADY008	3,482	3,494	-12	0	ADY008_Lowerelkriver
58_AMY001	1,342	1,342	0	0	58_Amy001_Yampa@Steamboa
58_FDP001	0	0	0	0	Fu_Dev_58
Basin Total	498,994	500,208	-1,173	0	

Reservoir Calibration Results

Figures D.7 through D.10 (located at the end of this appendix) present reservoir EOM contents estimated by the model using the Calculated data set, compared to historical observations, at selected reservoirs. Comments in Section 7 regarding reservoir calibration are applicable to the Calculated Data set results, although the latter exhibit slightly more use of all the reservoirs.

Figure D.1

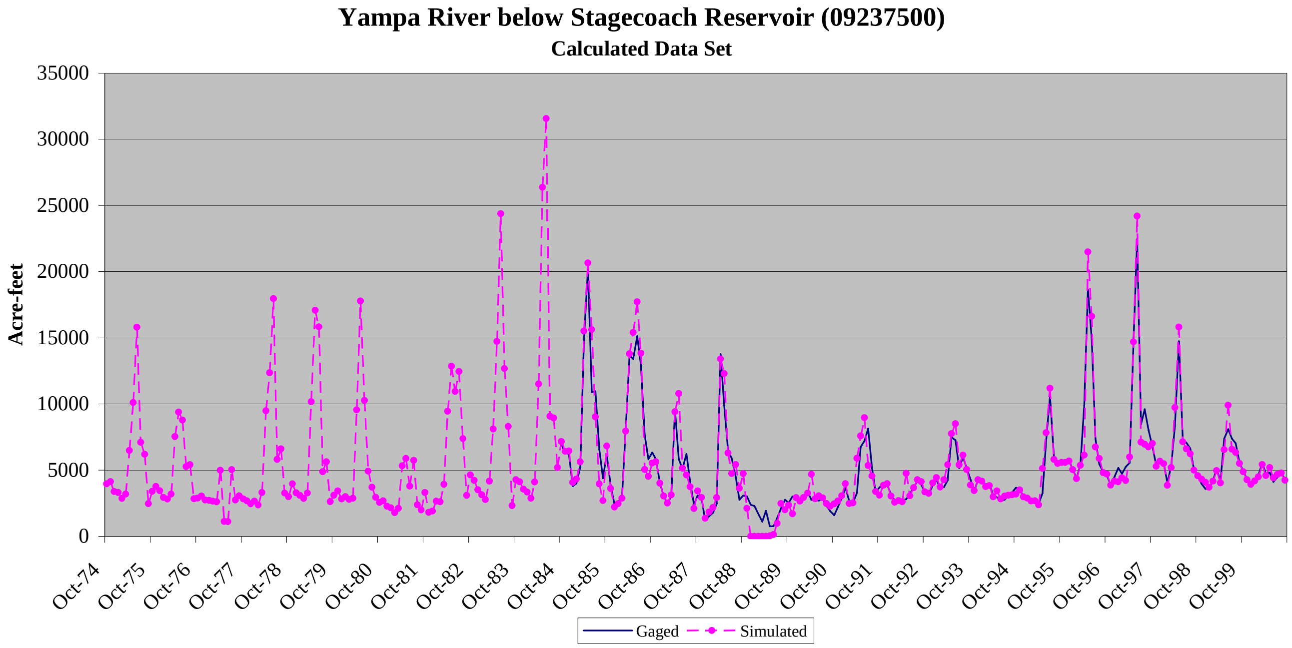


Figure D.2

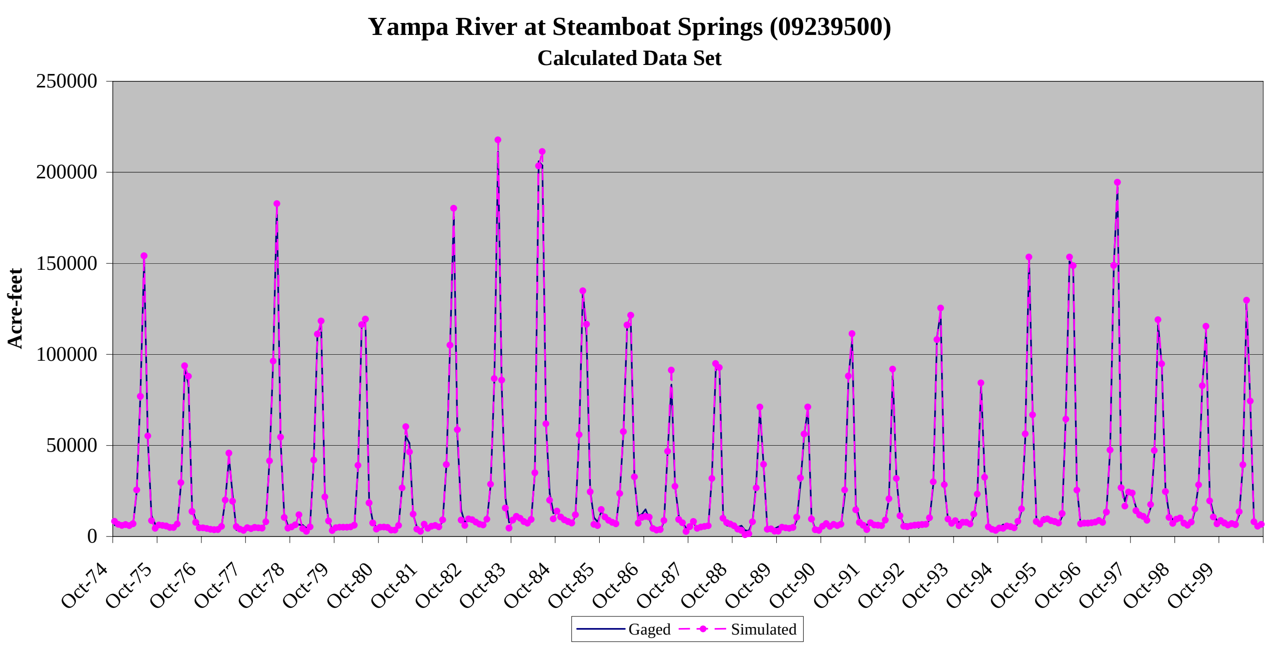
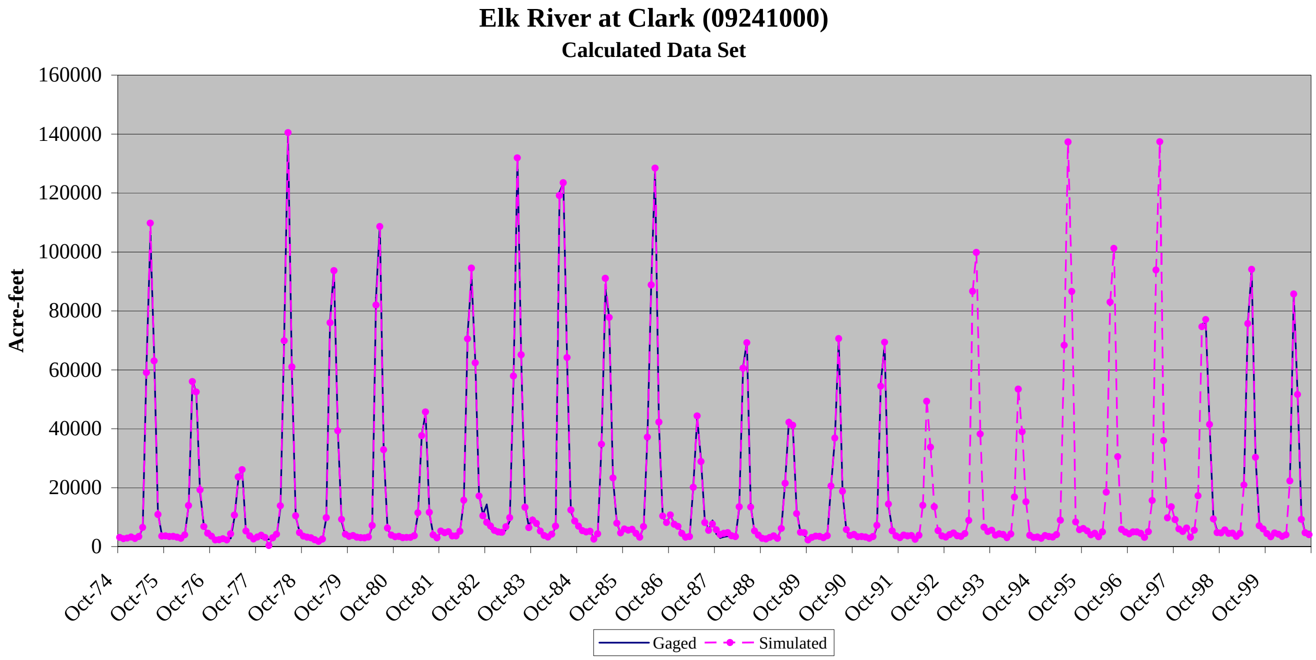


Figure D.3



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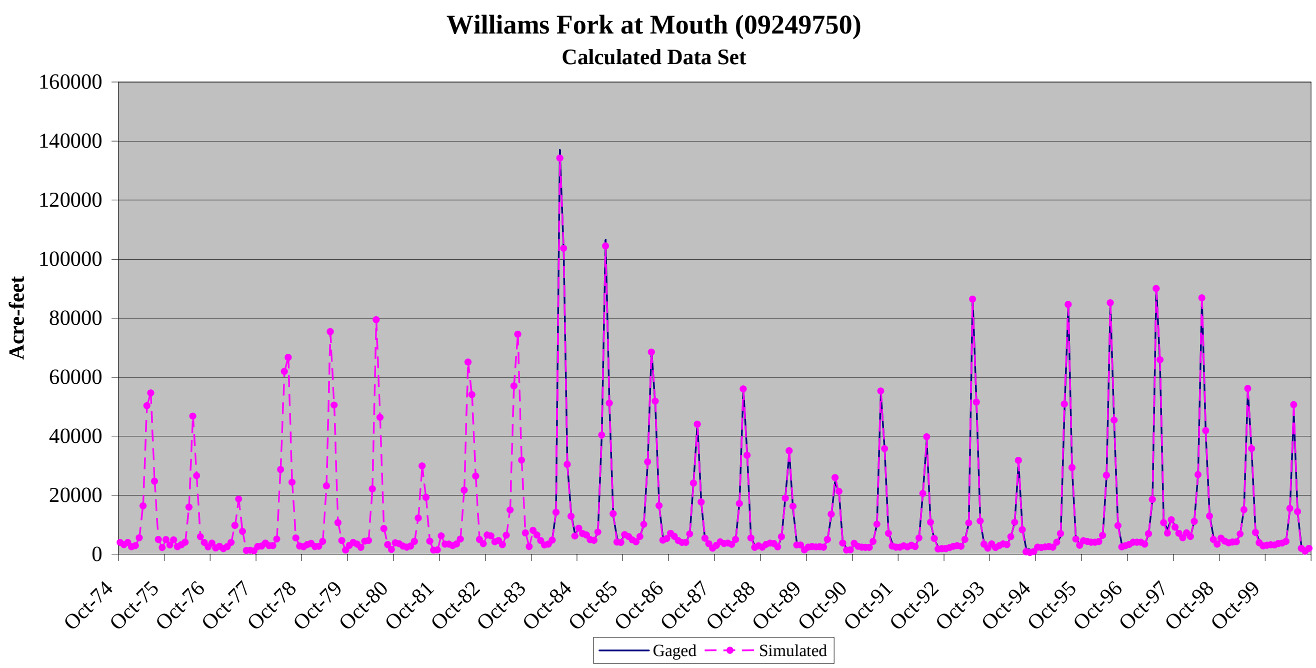

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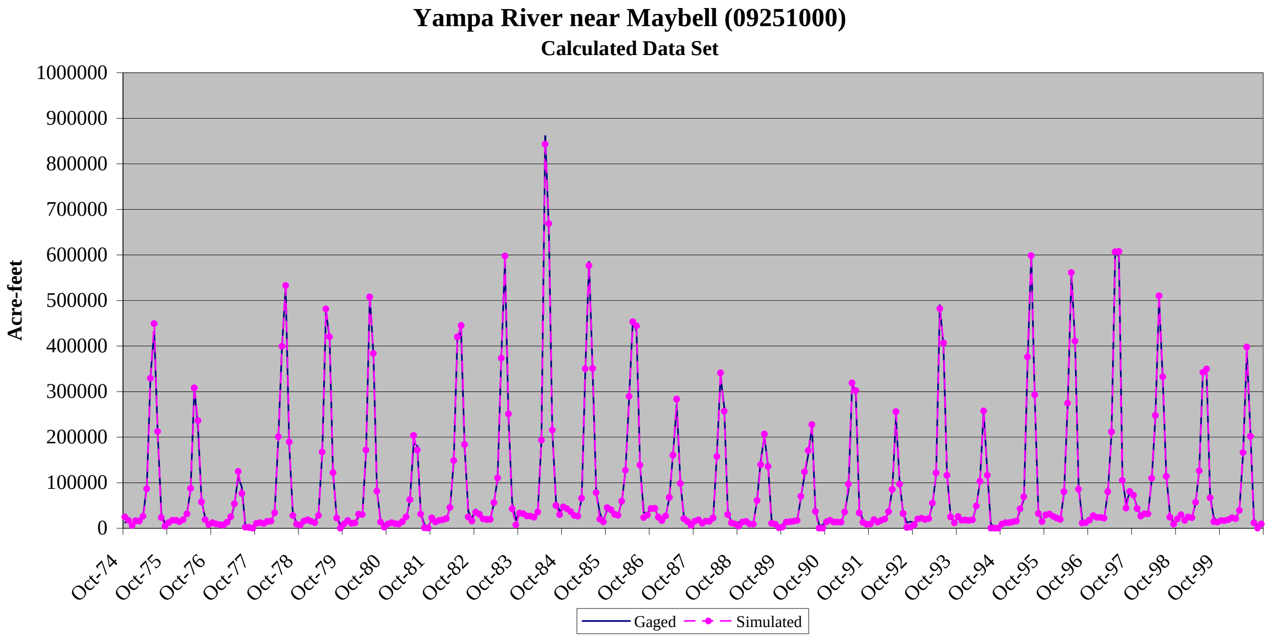

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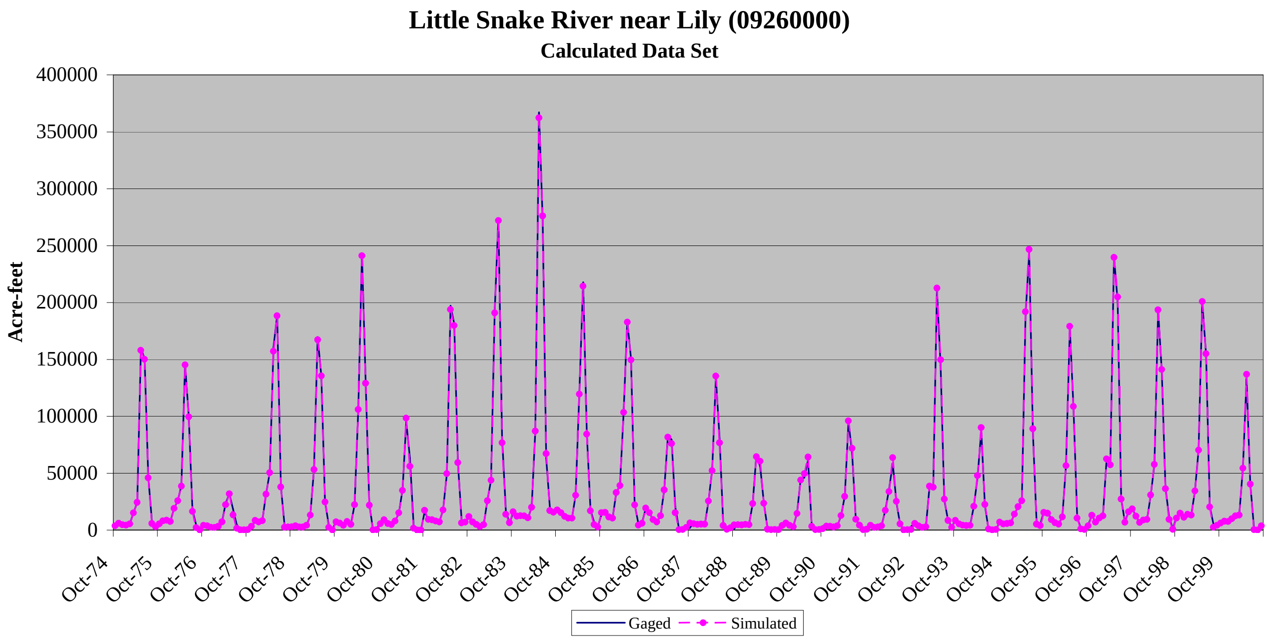

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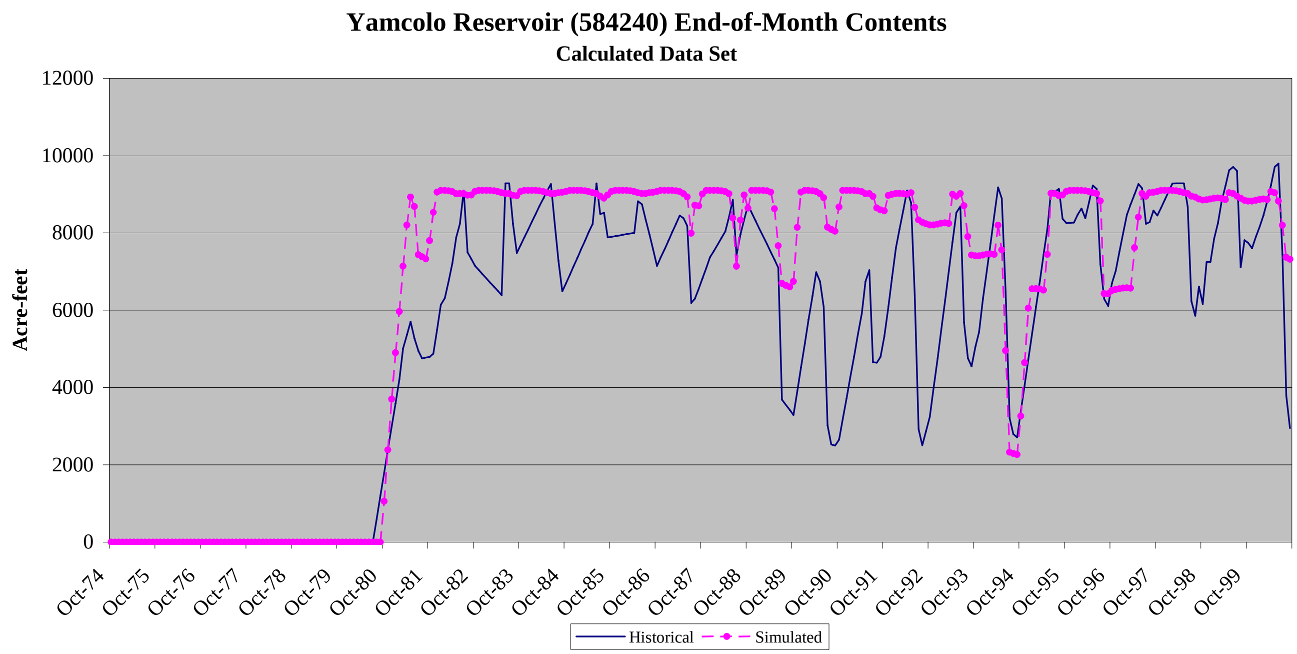


Figure D.8

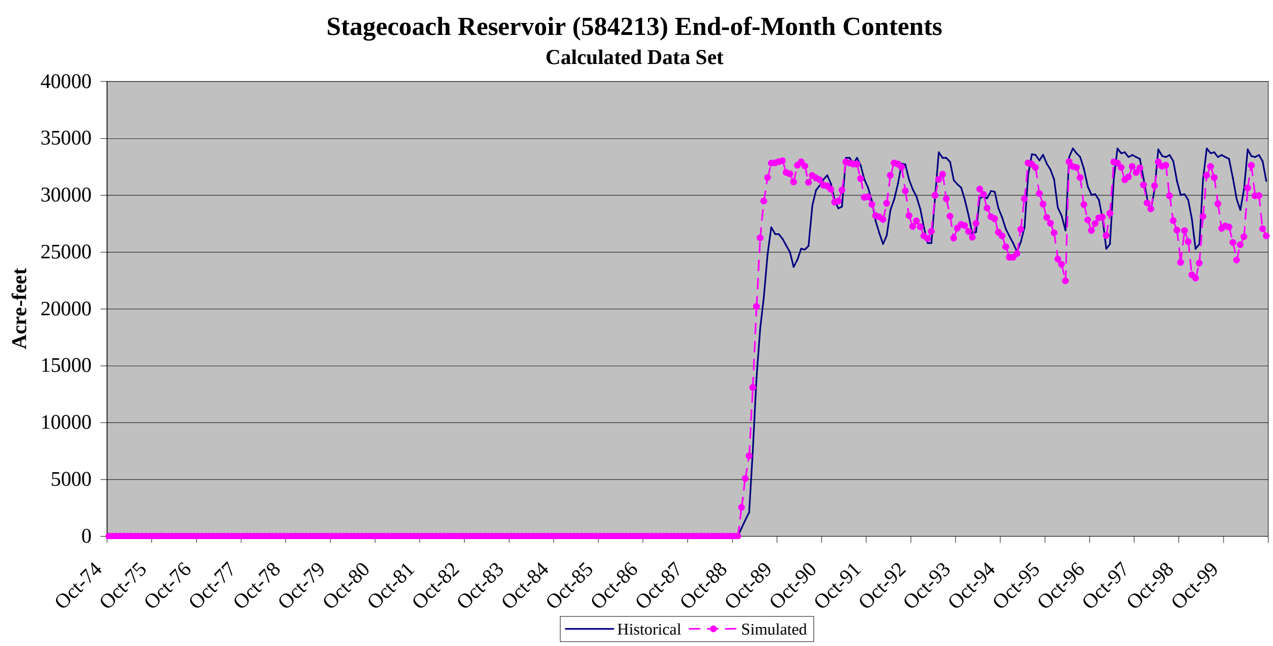


Figure D.9

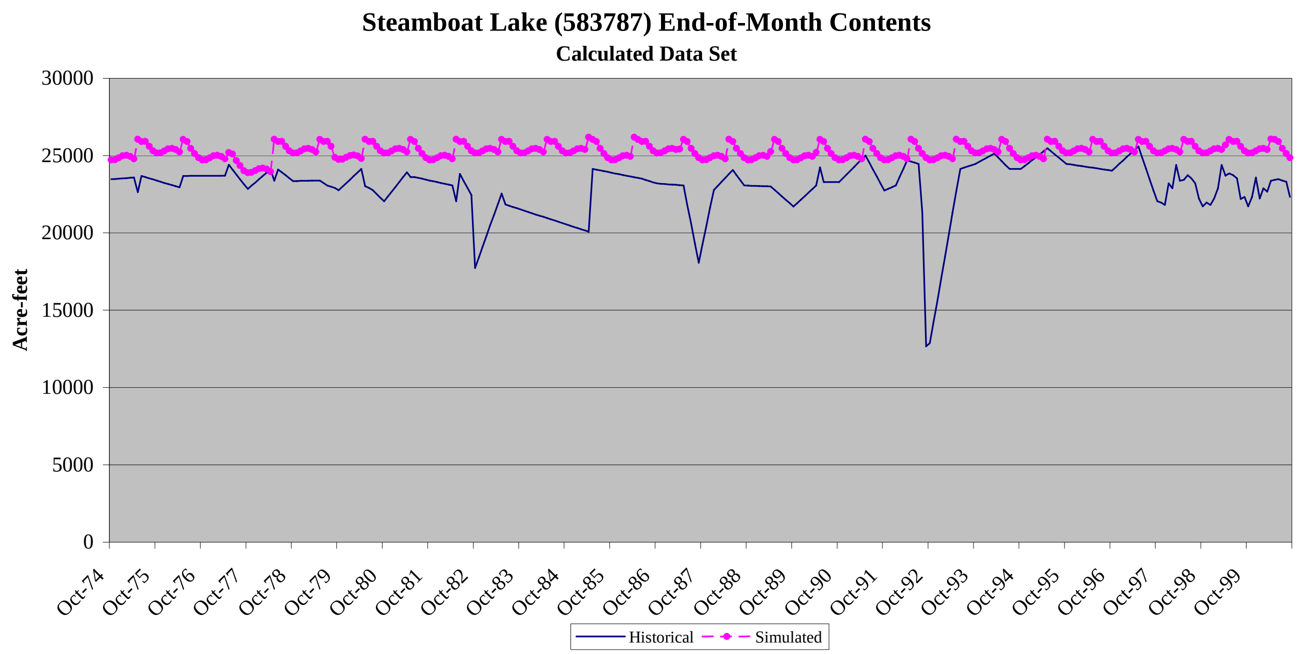
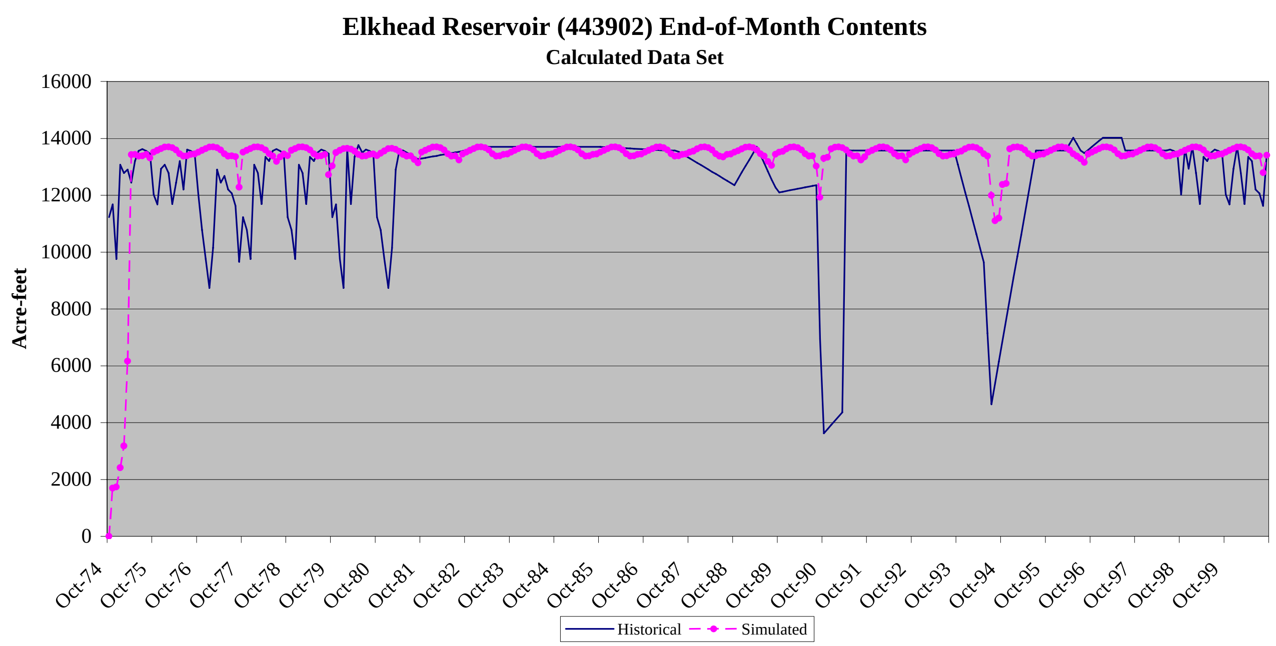


Figure D.10



Appendix E

Daily Baseline Model

Note: The Daily Baseline Model described here is an extension of the monthly Yampa model developed in 2004. When the monthly model was updated in 2009, the Daily Baseline Model was not updated. Users can follow the method described here to produce a daily version of the most recent Yampa model.

Daily Baseline Model

The “Daily Baseline” data set simulates current demands, current infrastructure and projects, and the current administrative environment on a daily time step, as though they had been in place throughout the modeled period. The purpose of the Daily model data set is to capture daily variations in streamflow and call regime.

The Yampa River planning model served as the example in a pilot study completed in 2002, to investigate various methods for creating a daily model from a monthly model. Developing a monthly model first allows the user to develop and confirm an understanding of the hydrologic system and legal and operational environment, without developing the volume of information ultimately required for a daily model. Furthermore, this approach to daily modeling has the benefit of being less data-intensive than using actual daily observations to build data sets. Because daily data are often incomplete and typically require filling, the loss of accuracy in going to disaggregation of monthly information can be minimal. The pilot study experimented with different approaches to disaggregating various input parameters, and recommended an approach that has generally been applied in other CDSS basin models.

Specifically, daily baseflows are estimated using StateMod’s Daily Pattern approach. StateMod calculates each day’s baseflow by disaggregating monthly baseflows using the daily pattern of flow at selected historical gages. Availability of representative “pattern gages” is critical to calibration of the daily model. The pattern gages must be available or be reliably estimated throughout the study period, and they need to exhibit runoff characteristics appropriate to the areas where they are applied to the baseflow. For this reason, presence of pattern gage records was the primary criterion in selecting a study period of 1954-2002 for the Yampa River daily model.

Monthly Baseline demands were disaggregated to daily demands by linearly connecting the midpoints of the monthly demand data. Reservoir targets were disaggregated by connecting the end points of monthly target data. Instream flow demands were disaggregated by setting them to the average daily value.

Daily return flow delay patterns which replicate the return flow timing used in the monthly model were developed. This was done by executing the same analytical tool used to produce monthly groundwater-surface water interaction parameters, but using a single daily time step.

Operating rights are the same in the monthly and daily Baseline models.

Where to find more information

- The CDSS Technical Memorandum "CDSS Daily Yampa Model - Task 3 Selecting a Daily or Monthly Model" gives guidance on determining whether a daily model is needed or appropriate, as well as advantages and tradeoffs in selecting a monthly or a daily model.

Daily Baseline Data Set

This section describes unique StateMod input files in the Daily Baseline Data Set. The data set is expected to be a starting point for users who want to apply the Yampa River water resources planning model to a particular management issue on a daily basis. As with the monthly Baseline Data set, the investigator may want to understand how the river regime would change under a new use or different operations. The change needs to be quantified relative to how the river would look today absent the new use or different operation, which may be quite different from the historical record. The Daily Baseline data set provides a basis against which to compare future scenarios. Users may opt to modify the Daily Baseline data set for their own interpretation of current or near-future conditions.

The daily Baseline data set, and corresponding daily results, does not include any consideration for Colorado River Compact obligations, nor are conditional water rights represented in the daily Baseline data set. Variations of the daily Baseline data set could include conditional rights within the Yampa Basin, and would likely result in less available flow than presented here.

The following detailed, file-by-file description is intended to provide enough detail that modifications can be made by the user with confidence. This section describes only input files that are different from the monthly Baseline Data Set, or daily features of files used in both daily and monthly data sets. Daily-oriented input in these files is generally ignored when the model is run with a monthly time step.

This section is divided into the following subsections:

- Response File describes the response file, which simply lists names of the rest of the data files. The section tells briefly what is contained in each of the named files, and whether the daily Baseline data set files are different from the monthly Baseline data set files.
- Control File describes the control file, which sets the execution parameter for the daily simulation.
- River System Files describes the streamflow files that define the disaggregation of monthly baseflow files.
- Daily Diversion Demands, Reservoir Targets, and Instream Flow Demands includes files that define the methodology for disaggregating monthly demands and reservoir targets for the daily simulation.
- Daily Return Flow Delay Patterns File describes the daily return flow delay pattern file.

Where to find more information

- The CDSS Technical memorandum “CDSS Daily Yampa Model – Task 2 Pilot Study” describes the investigation into StateMod’s daily modeling approaches and the recommended approach for subsequent daily modeling of CDSS basins.
- For generic information on every daily input file listed below, see the StateMod documentation. It describes how input parameters are used, as well as format of the files.
- The input files that are common to the Baseline data set and the Daily Baseline data set are described in detail in Section 5 – Baseline Data Set.

Response File (*.rsp)

The response file (*ym2004Db.rsp*) contains the names of all other data files required to run the model. The file is changed by hand-editing. As with the name of the response file itself, files that are unique to the daily data set, but have a counterpart in the monthly model, have the letter “D” inserted after the root name “ym2004”. The “b” ending indicates that this file is unique to the baseline data set, as compared to the Historical data set. The file *ym2002.dum* continues to be used for an empty dummy file, and is referenced in the response file for all the StateMod input file types that are not needed for this particular simulation. The table below describes the response file entries.

File Name	Description	Reference
ym2004D.ctl	Control file – specifies execution parameters, such as run title, modeling period, options switches	Section 8.1.2
ym2004.rin	River network file – lists every model node and specifies connectivity of network	Section 5.3.1
ym2004b.res	Reservoir station file – lists physical reservoir characteristics such as volume, area-capacity table, and some administration parameters. The reservoir file also contains a switch governing how daily reservoir targets shall be either read in or created through disaggregation of monthly targets.	Section 5.6.1 & Section 8.1.4
ym2004.dds	Direct diversion station file – contains parameters for each diversion structure in the model, such as diversion capacity, return flow characteristics, and irrigated acreage served. The diversions station file also contains a switch governing how daily demand shall be either read in or created through disaggregation of monthly demand.	Section 5.4.1 & Section 8.1.4
ym2004.ris	River station file – lists model nodes, both gaged and ungaged, where hydrologic inflow enters the system. The river station file also contains a switch governing how daily baseflow shall be either read in or created through disaggregation of monthly baseflows.	Section 8.1.3
ym2004.ifs	Instream flow station file – lists instream flow reaches. The instream flow	Section 5.7.1 &

File Name	Description	Reference
	station file also contains a switch governing how monthly instream flow demand shall be either read in or created through disaggregation of monthly demand.	Section 8.1.4
ym2002.dum	Well station file (not used in the Yampa model)	N/a
ym2004.ifr	Instream flow right file – gives decreed amount and administration number of instream flow rights associated with instream flow reaches	Section 5.7.3
ym2004b.rer	Reservoir rights file – lists storage rights for all reservoirs	Section 5.6.5
ym2004.ddr	Direct diversion rights file – lists water rights for direct diversions	Section 5.4.5
ym2004C.opr	Operational rights file – specifies many different kinds of operations that are more complex than a direct diversion or an onstream storage right. Operational rights can specify, for example, a reservoir release for delivery to a downstream diversion point, a reservoir release to allow diversion by exchange at a point which is not downstream, or a direct diversion to fill a reservoir via a feeder	Section 5.8
ym2002.dum	Well rights file (not used in the Yampa model)	N/a
ym2002.dum	Annual precipitation file (not used in the Yampa model)	N/a
yampaF.eva	Evaporation file – gives monthly rates for net evaporation from free water surface	Section 5.6.2
ym2004Fx.xbm	Baseflow data file – monthly time series of undepleted flows at all nodes listed in *ym2004.ris*	Section 5.3.5
ym2004B.ddm	Monthly demand file – monthly time series of headgate demands for each direct diversion structure	Section 5.4.4 & Section 8.1.4
ym2002.dum	Monthly demand overwrite file (not used in the Yampa model)	N/a
ym2002.dum	Annual demand file (not used in the Yampa model)	N/a
ym2004.ifa	Instream flow demand file – gives the decreed monthly instream flow rates	Section 5.7.2 & Section 8.1.4
ym2002.dum	Well demand file (not used in the Yampa model)	N/a
ym2004.dly	Delay Table – contains several return flow patterns that express how much of the return flow accruing from diversions in one month reach the stream in each of the subsequent months, until the return is extinguished	Section 5.4.2 & Section 8.1.5
ym2004B.tar	Reservoir target file – monthly time series of maximum and minimum targets for each reservoir. A reservoir may not store above its maximum target, and may not release below the minimum target	Section 5.6.4 & Section 8.1.4
ym2004.ipy	CU Time series file – maximum efficiency and irrigated acreage by year and by structure, for variable efficiency structures	Section 5.5.2
ym2004.iwr	Irrigation Water Requirement file – monthly time series of crop water requirement by structure, for variable efficiency structures	Section 5.5.3
ym2004.par	Soil Parameter file – soil moisture capacity by structure, for variable efficiency structures	Section 5.5.1
ym2004.eom	Reservoir End of month contents file – Monthly time series of historical	Section 5.6.3

File Name	Description	Reference
	reservoir contents	
ym2004.rib	Baseflow Parameter file – gives coefficients and related gage ID's for each baseflow node, with which StateMod computes baseflow gain at the node	Section 5.3.3
ym2004.rih	Historical streamflow file – Monthly time series of streamflows at modeled gages	Section 5.3.4
ym2004.ddh	Historical Diversions – Monthly time series of historical diversions	Section 5.4.3
ym2002.dum	Historical well pumping (not used in the Yampa model)	N/a
ym2002.dum	GIS file	N/a
ym2004.xou	Output control file	Statemod documentation
ym2004.rid	Daily historical streamflow file	Section 8.1.3
ym2002.dum	Daily direct flow demand file (not used in the Yampa model)	N/a
ym2002.dum	Daily instream flow demand file (not used in the Yampa model)	N/a
ym2002.dum	Daily well demand file (not used in the Yampa model)	N/a
ym2002.dum	Daily reservoir target file (not used in the Yampa model)	N/a
ym2004.dld	Daily return flow delay pattern file	Section 8.1.5
ym2002.dum	Daily consumptive water requirement file (not used in Yampa model)	N/a
ym2004.riy	Daily historical streamflow file	Section 8.1.3
ym2002.dum	Daily historical diversion file (not used in the Yampa model)	N/a
ym2002.dum	Historical reservoir end-of-day content file (not used in the Yampa model)	N/a

Control File

The control file, which is created and maintained by editing manually, contains information that controls the model simulation. There are two essential differences between the monthly and daily control files: 1) the *iday* variable is set to "1" to indicate the simulation is performed using a daily time-step, and 2) the starting and ending years for daily simulation are 1954 and 2002, respectively. The run title, input at the top of the file, indicates that this is a daily simulation.

River System Files

The daily pattern approach can be described as distributing monthly baseflows to daily baseflows based on the daily distribution of selected historical gages, or pattern gages. Statemod disaggregates the monthly baseflows by multiplying the daily historical pattern gage flow QDgage by the factor QMbf/QMgage, where QMbf is the monthly baseflow and QMgage is the monthly historical gage flow.

Two files work in conjunction to define the daily baseflows used in the Daily Baseline simulations; the river station file (ym2004.ris) and the daily streamflow file (ym2004.rid).

River Station File

In the Yampa model, the river station file is the same for the monthly and daily model. When a simulation is run with a monthly time step, the "Daily ID" variable is ignored. For a daily time step simulation, this variable holds the station ID (typically, the USGS gage number) of the pattern gage to use in distributing monthly baseflow across the days of the month. The pattern gages were selected based on the following criteria:

- Completeness of Daily Records. The streamflow gages within the Yampa Model were reviewed for completeness of daily records. Only gages with complete or nearly complete records were considered as pattern gages.

- Basin and Baseflow Representation. Representative pattern gages were then selected based on the location and minimal upstream effects. Ideally, pattern gages should closely represent baseflows, having minimal influence from upstream diversions or storage. In comparison with other Colorado basins, the Yampa has a small amount of storage. Therefore, reservoir operations have small influence, relative to total flow, on lower basin flows.

- Baseflow Comparison. Average historical monthly flows were compared to the average baseflows calculated using StateMod to quantify the upstream effects and verify the gage selections.

Table E.1 lists the pattern gages, their periods of record, and the areas where they were applied. Figure E.1 shows application of the pattern gages schematically.

Table E.1

Daily Pattern Gages Used for Yampa River Sub-basins

Pattern Gage	Period of Record	Basin Subdivision Assignment
09238900 Fish Creek at Upper Station	1966-1972, summer months only 1973-1979, 1983-2002	Fish Creek basin
09239500 Yampa River at Steamboat Springs, CO	1910 - 2002	Bear River, Yampa River above Hayden, except for the Fish Creek and Elk River basins.
09241000 Elk River near Clark, CO	1932-1991, summer months only 1998-2002	Elk River basin
09245000 Elkhead Creek near Elkhead, CO	1953-1996	Elkhead and Fortification Creek basins
09251000 Yampa River near Maybell, CO	1916-2002	Yampa River from the Town of Craig to the Green River, Williams Fork basin below Waddle Creek
09253000 Little Snake River near Slater, CO	1943-1947, 1950-1999, 4/2001-9/2002	Little Snake mainstem from headwaters to Lily gage
09255000 Slater Fork near Slater, CO	1932 - 2002	Slater Fork and Savery Creek basins
09258000 Willow Creek near Dixon	1954 - 1992	Willow Creek and Muddy Creek
09260000 Little Snake River near Lily, CO	1922 - 2002	lower Little Snake River

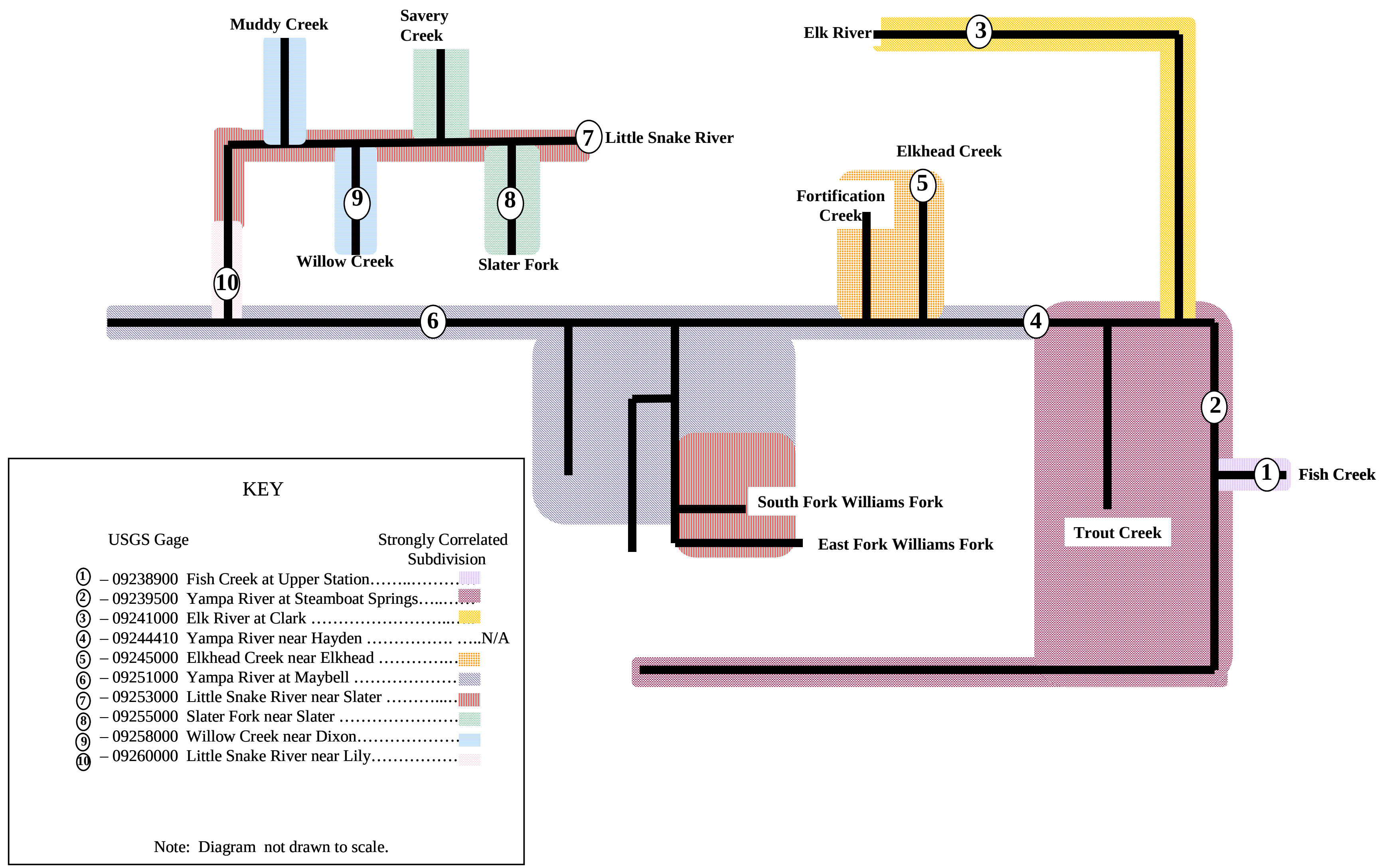


Figure E.1 – Geographical Application of Daily Pattern Gages

Assignment of a pattern gage to a subdivision of the basin was a matter of engineering judgment and calibration. On the mainstem below Steamboat Springs, daily hydrographs are similar, and both the Steamboat Springs gage and the Maybell gage could have provided the pattern for the intervening gages at Hayden and Craig. Tributaries, by comparison, tend to have unique runoff patterns. Those tributaries where a pattern gage was located (Fish Creek, Elk River, Elkhead Creek, and the tributaries of the Little Snake basin) were assigned the in-basin gage as their pattern gage.

After some experimentation and consideration of both the Fish Creek and Elk River gages, the Steamboat Springs gage was used to pattern the Bear River and upper Yampa. The Steamboat Springs gage was also selected for Trout Creek, although the lack of gaging on Trout Creek makes it difficult to assess how appropriate the choice was. Fortification Creek baseflows are patterned after the Elkhead Creek near Elkhead gage. Fortification Creek is the next major tributary below Elkhead Creek, and they are both north side tributaries. Comparisons of daily hydrographs for the Williams Fork gages and the pattern gages showed that both the Little Snake River at Slater and the Yampa River at Maybell possessed similar timing to Williams Fork. In general, the upper Little Snake hydrograph resembled the Williams Fork more closely during the rising stages, but dropped too quickly on the falling limb. The Maybell gage was a better fit in the late season, but a poorer fit than the Little Snake in the early season. Based on these observations, the Little Snake gage was selected to pattern the upper Williams Fork basin, and the Maybell gage was selected to pattern the lower Williams Fork.

Daily Historical Streamflow File

The daily historical streamflow file (ym2004.rid) contains daily streamflows extracted from HydroBase for the pattern gages. Five of the nine pattern gages required some filling of both monthly and daily values to provide complete data sets. In general, monthly values were filled by regression against other gages included in the model. Twelve monthly models were developed, and the station that provided the best results in the most months was selected as the independent gage. Resulting monthly runoff values were then distributed to daily flows using the pattern of a gage selected for similarity in daily flows as observed in whatever common record was available. Compared with the requirements for developing a regression model, selection of a daily pattern gage requires a shorter common record. For instance, five annual cycles of the hydrograph give a good indication of whether a candidate gage is suitable, or which of several candidates is preferable. Therefore, short term gages that are not included in the Yampa model were used as appropriate to disaggregate monthly flows to daily flows. The five gages were filled using the following information:

- 09238900 Fish Creek at Upper Station – gage records had to be estimated for water years 1954 through 1965, the non-irrigation months of 1973-1979, and water years 1980-1982. Monthly values were filled by regression on gage 09239500 Yampa River at Steamboat Springs gage, and daily timing was taken from gage 09241000 Elk River at Clark.

- 09241000 Elk River at Clark – gage records had to be estimated for water years 1992-1997, and for non-irrigation months after that. Monthly values were filled by regression on gage 09253000 Little Snake River near Slater, and daily timing was taken from

09242500 Elk River at Milner, downstream from the Clark gage. The Milner gage is a better daily distributor than the Little Snake gage in the falling limb of the hydrograph, during which Little Snake River drops off more quickly than the Elk River.

- 09245000 Elkhead Creek near Elkhead – gage records had to be estimated for water years 1997-2002. Monthly values were filled using log linear regression on gage 09260050 Yampa River at Deerlodge. Daily hydrographs for Elkhead Creek near Elkhead were compared with daily hydrographs for 09249750 Williams Fork near Mouth, 09255000 Slater Fork near Slater, and 09246200 Elkhead Creek above Long Gulch. The last gage is downstream from the "near Elkhead" gage and co-exists for only one year. The Slater Fork gage would be a good predictor of daily flows in the early season, but its falling limb stays higher and persists longer than the Elkhead gage. The same is true for the Williams Fork gage. Elkhead Creek above Long Gulch fits Elkhead Creek near Elkhead well in the one year of common record. Furthermore, the Long Gulch gage has several years in common with the Slater Fork and Williams Fork gages, in which it "undershoots" both gages during the falling limb. From this indirect comparison, the Long Gulch gage was selected as the daily distributor for Elkhead Creek near Elkhead.

- 09253000 Little Snake River near Slater – gage records had to be estimated for water year 2000 and the first half of water year 2001. The best candidate for monthly filling was clearly 09260050 Yampa River at Deer Lodge, compared with 09255000 Slater Fork near Slater, 09249750 Williams Fork at Mouth, and 09251000 Yampa River at Maybell. On the other hand, when daily hydrographs for all these gages were compared, Slater Fork appeared to resemble the Little Snake gage most closely, and was selected for daily distribution.

- 09258000 Willow Creek near Dixon – gage records had to be estimated for water years 1993-2002. 09255000 Slater Fork near Slater was the best candidate both in terms of monthly flow estimation and daily distribution.

Daily Diversion Demands, Reservoir Targets, and Instream Flow Demands

The daily flag variable (*cdividy)* was set equal to "4" for all diversion stations in the direct diversion station file (*ym2004.dds*). This flag instructs StateMod, while in daily simulation mode, to disaggregate the monthly diversion demands found in the diversion demand file (*ym2004b.ddm*) by connecting the midpoints of the monthly data.

The daily flag variable (*cresidy*) was set equal to "5" for all reservoirs in the Baseline reservoir station file (*ym2004b.res*). This flag instructs StateMod, while in daily simulation mode, to develop daily targets by linearly "connecting" end-of-month reservoir targets found in the reservoir target file (*ym2004b.tar*).

The daily flag variable (*cifrdy*) was set equal to "0" for all instream flow nodes in the instream flow station file (*ym2004.ifs*). This flag instructs StateMod, while in daily simulation mode, to disaggregate the monthly instream flow demand found in the instream flow file (*ym2004.ifa*) to daily values by setting them to the average daily value.

Note that the variables described in this section are set when developing the monthly Baseline data set, but are only used by StateMod when the daily option is selected in the control file.

EDaily Return Flow Delay Patterns File

The daily return pattern file (*ym2004.dld*), which is hand-built with a text editor, describes the estimated re-entry of return flows into the river system on a daily basis. When applied to 30 (or 31) days of return flows occurring at a constant rate, they produce the same result as the corresponding monthly return flow pattern (*ym2004.dly*), applied to one month's return flow at the same constant rate.

Where to find more information

- CDSS Memorandum "Colorado River Basin Representative Irrigation Return Flow Patterns", Leonard Rice Engineers, January, 2003. *(Technical Papers)*
- CDSS Technical Memorandum "CDSS Daily Yampa Model Subtask 1 - Equivalent daily return flow factors" was created as part of the daily modeling pilot study. It describes how to develop and validate daily return flow factors having the same effect as specified monthly return flow factors. The approach was applied, in this version of the Yampa model, to regionalized monthly return flow patterns calculated by Leonard Rice Engineers per the above citation.

Daily Baseline Streamflows

Table E.2 shows, for each gage, the average annual available flow from the Daily Baseline simulation compared to the average annual available flow from the Monthly Baseline simulation. The average is based on the period common to the two models, 1954-2002. Available flow at a point is water that is not needed to satisfy instream flows or downstream diversion demand; it represents the water that could be diverted by a new water right. In general, available flow is greater for the Monthly Baseline simulation than the Daily Baseline simulation. Daily simulation better represents large flow events that occur within a monthly time step, and in general, junior diverting structures can take advantage of these flows even if they are out-of-priority for much of the month. As a result, consumptive use is higher in the daily model, leaving less available flow in the streams.

Temporal variability of the Daily Baseline and Monthly Baseline simulated flows are illustrated for selected gages in Figures E.2 through E.38. The figures represent three selected years for a sampling of gages which includes both pattern and non-pattern gages. The selected years represent wet (1983 or 1985 depending on gage availability), average (1988), and dry (2002, 1977, or 1990 depending on gage availability) years in the Yampa Basin. The historical gaged streamflow is also shown on these graphs, only to provide frame of reference. The baseline simulated streamflows may not match the historical gages because demands, operations, and storage supplies differ from historical conditions. (For a sense of how well the historical daily model replicates historical daily gages, see Appendix F.) As shown, daily simulated streamflow represents the daily large and small flow events that occur within a monthly time step.

In the daily modeling efforts, the release to target rule used to mimic hydropower operations uses a monthly storage target. At this time, there appears to be a discrepancy between the releases to this monthly target on the first day of each simulated year (October 1) compared to the releases to this monthly target for the remaining months in the year. This discrepancy was first identified in the Gunnison basin model, and it is expected that future StateMod code enhancements will correct this discrepancy. In the Yampa model, the “spike” can be seen most clearly at USGS gage 092395000 Yampa River at Steamboat Springs. It is unclear why it does not show up in hydrographs for the gage below Stagecoach Reservoir, since Stagecoach is the presumed source of the spike. It is important to note that this “spike” flow does not affect overall results or usefulness of the model.

Table E.2
Baseline Average Annual Available Flows for Yampa Model Gages (1954-2002)
Daily Simulation Compared to Monthly Simulation

Gage ID	Gage Name	Daily Simulated Available Flow (af)	Monthly Simulated Available Flow (af)	Difference Daily less Monthly (af)	% Different
9236000	Bear River Near Toponas	3,320	2,772	548	16.5%
9237500	Yampa River Below Stagecoach	58,093	59,466	-1,373	-2.4%
9238900	Fish Creek At Upper Station	44,210	44,106	104	0.2%
9239500	Yampa River At Steamboat Springs	311,074	314,282	-3,208	-1.0%
9241000	Elk River At Clark	168,049	168,060	-11	0.0%
9244410	Yampa River Below Diversion near Hayden	691,118	697,876	-6,758	-1.0%
9245000	Elkhead Creek Near Elkhead	39,151	39,058	93	0.2%
9245500	North Fork Elkhead Creek	13,682	13,620	62	0.5%
9246920	Fortification Creek near	7,430	7,372	58	0.8%
9247600	Yampa River Below Craig	874,336	884,872	-10,536	-1.2%
9249000	East Fork Of Williams Fork	72,253	72,451	-198	-0.3%
9249200	South Fork Of Williams Fork	29,198	29,162	36	0.1%
9249750	Williams Fork At Mouth	151,761	153,281	-1,520	-1.0%
9251000	Yampa River Near Maybell	1,014,086	1,028,397	-14,311	-1.4%
9253000	Little Snake River Near Slater	147,246	145,255	1,991	1.4%
9255000	Slater Fork Near Slater	55,120	54,805	315	0.6%
9255500	Savery Creek near Upper Station	32,373	32,100	273	0.8%
9256000	Savery Creek near Savery	70,644	70,283	361	0.5%
9257000	Little Snaker River Near Dixon	325,568	328,565	-2,997	-0.9%
9258000	Willow Creek Near Dixon	4,728	4,755	-27	-0.6%
9260000	Little Snake River Near Lily	370,767	380,498	-9,731	-2.6%
9260050	Yampa River At Deerlodge Park	1,428,488	1,453,308	-24,820	-1.7%

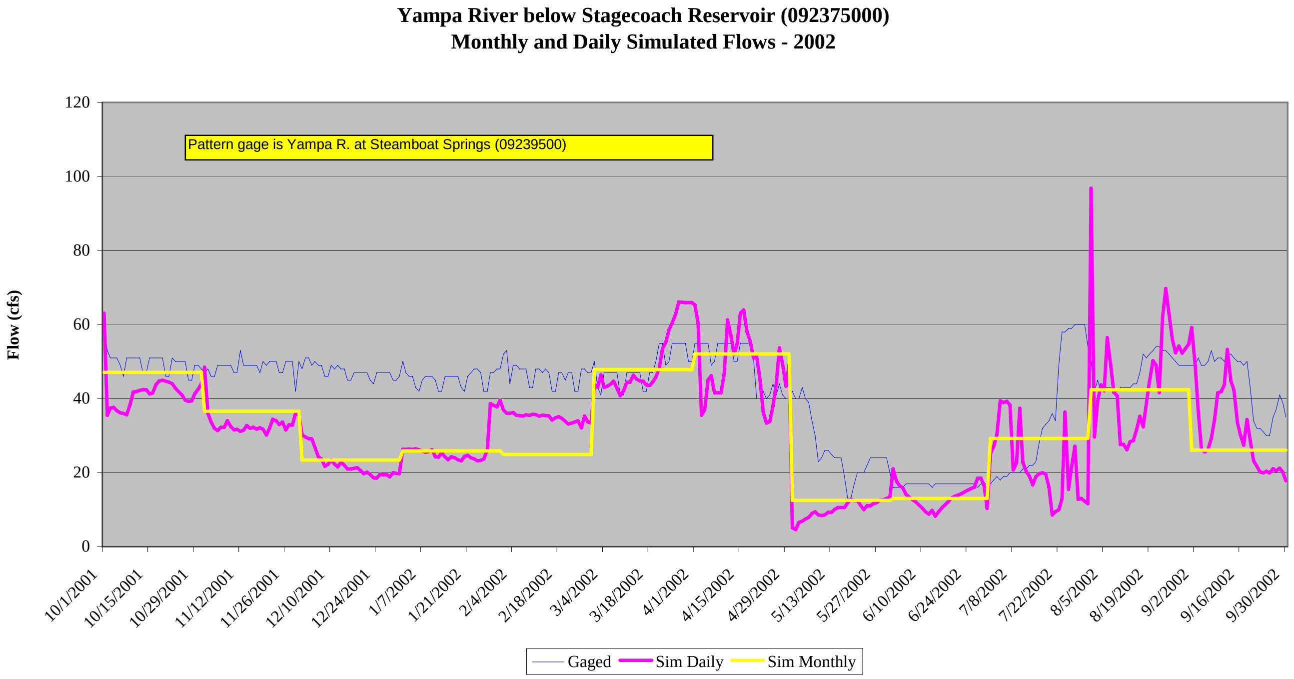


Figure E.2 Daily Baseline Comparison, Dry Year – Yampa River Below Stagecoach Reservoir

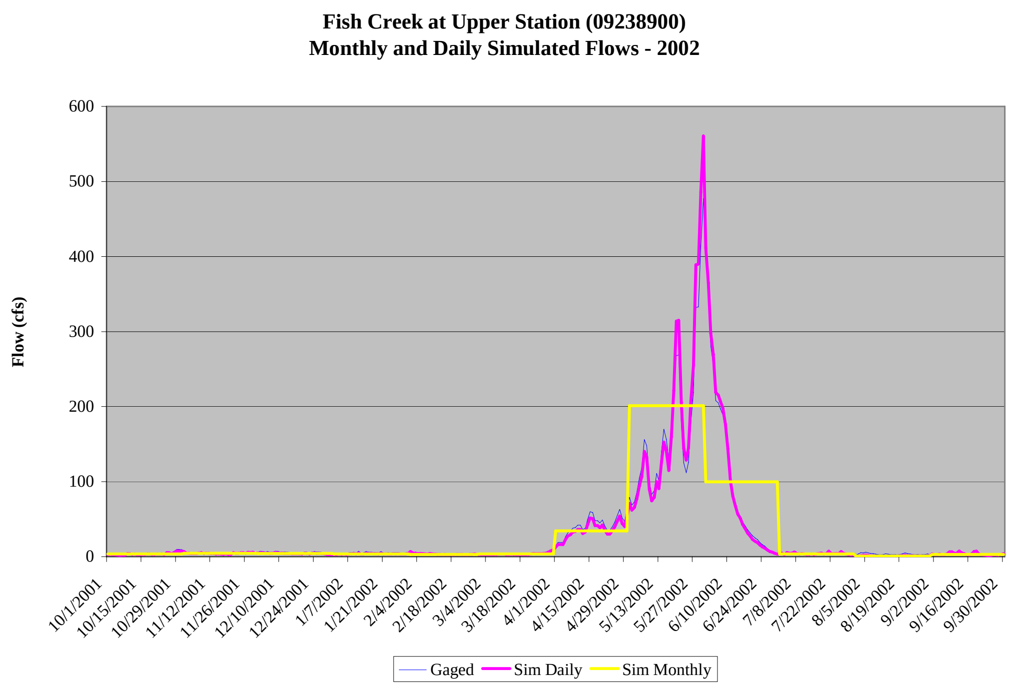


Figure E.3 Daily Baseline Comparison, Dry Year – Fish Creek at Upper Station

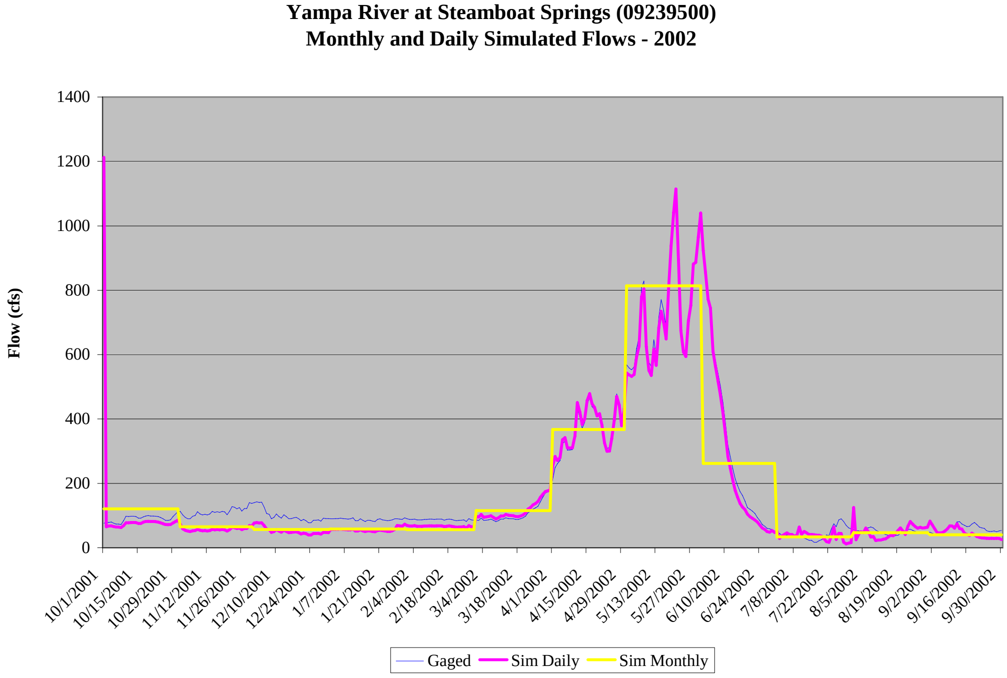


Figure E.4 Daily Baseline Comparison, Dry Year – Yampa River at Steamboat Springs

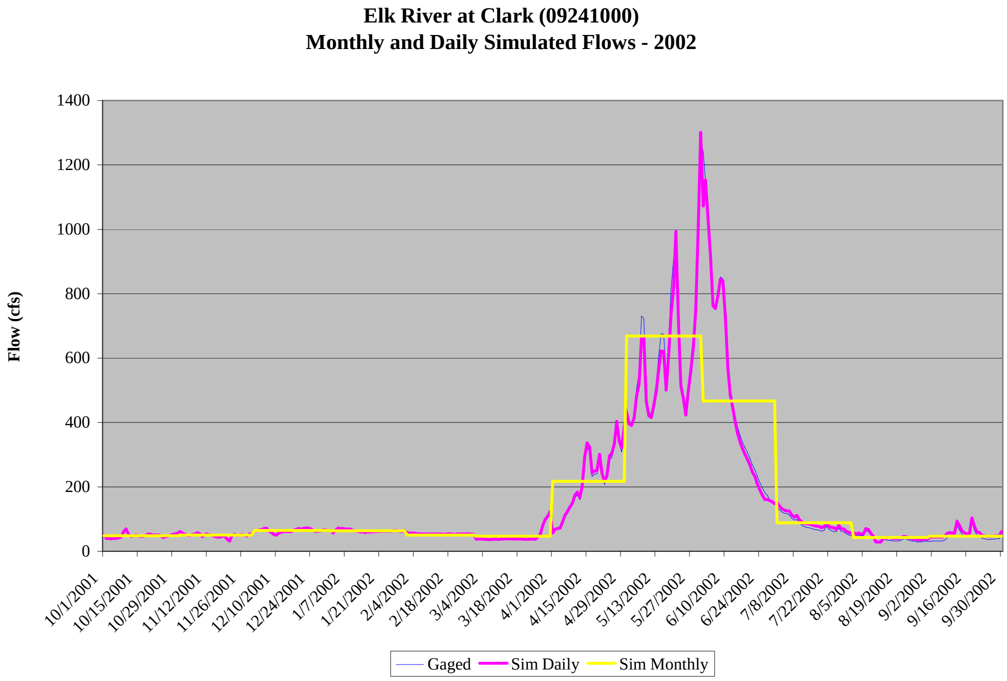


Figure E.5 Daily Baseline Comparison, Dry Year – Elk River at Clark

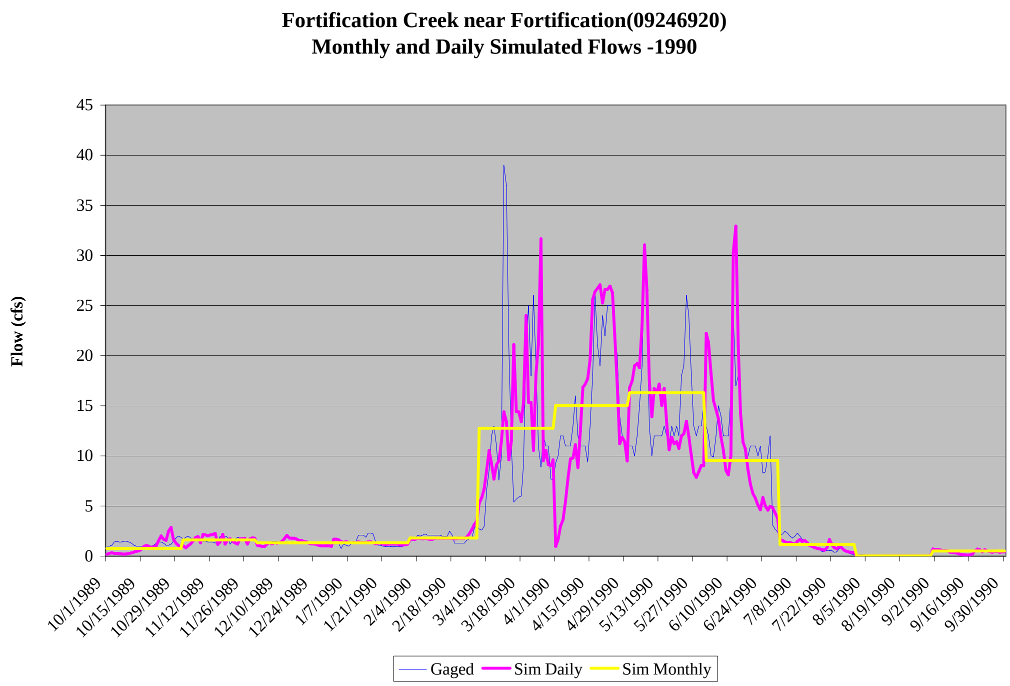


Figure E.6 Daily Baseline Comparison, Dry Year – Fortification Creek Near Fortification

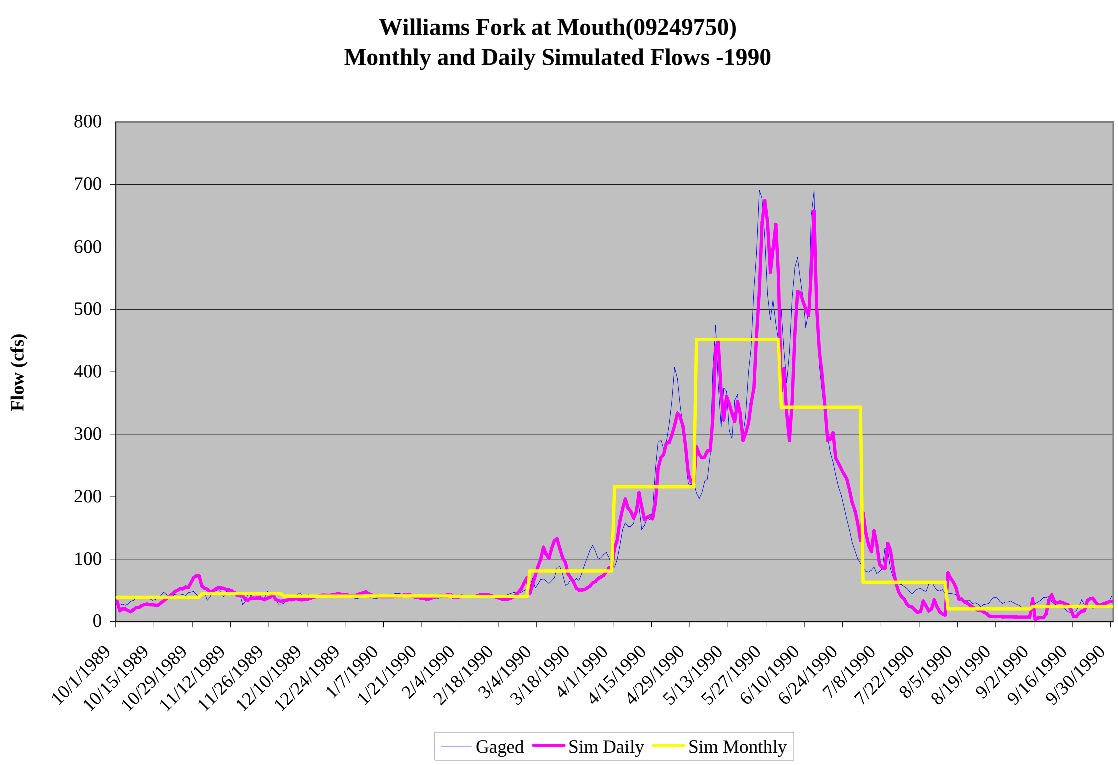


Figure E.7 Daily Baseline Comparison, Dry Year, Fortification Creek Near Fortification

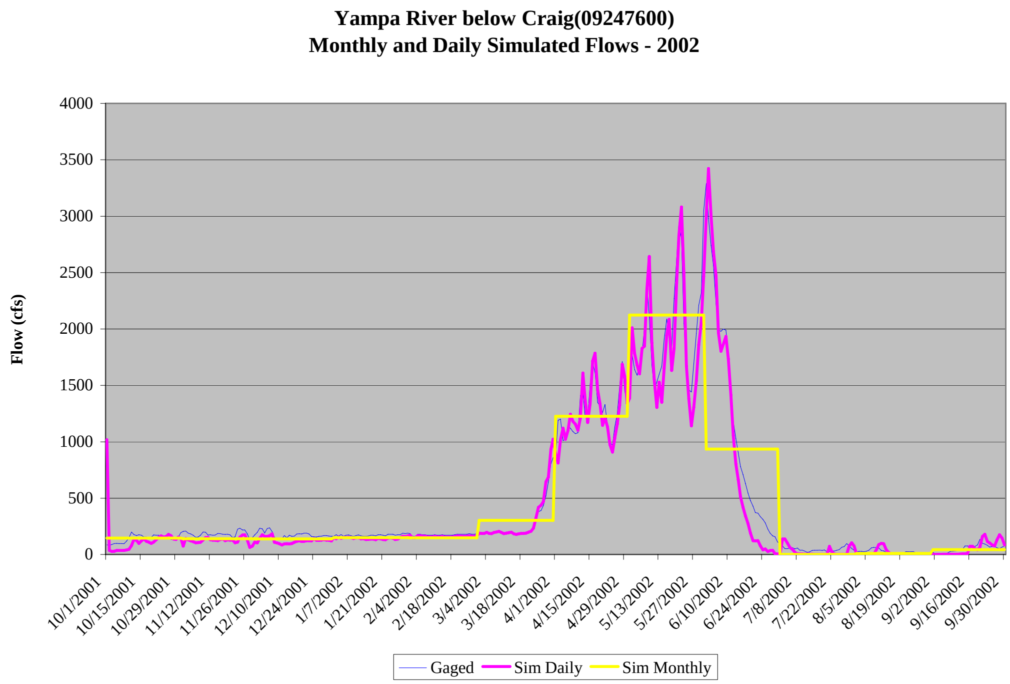


Figure E.8 Daily Baseline Comparison, Dry Year – Yampa River Below Craig

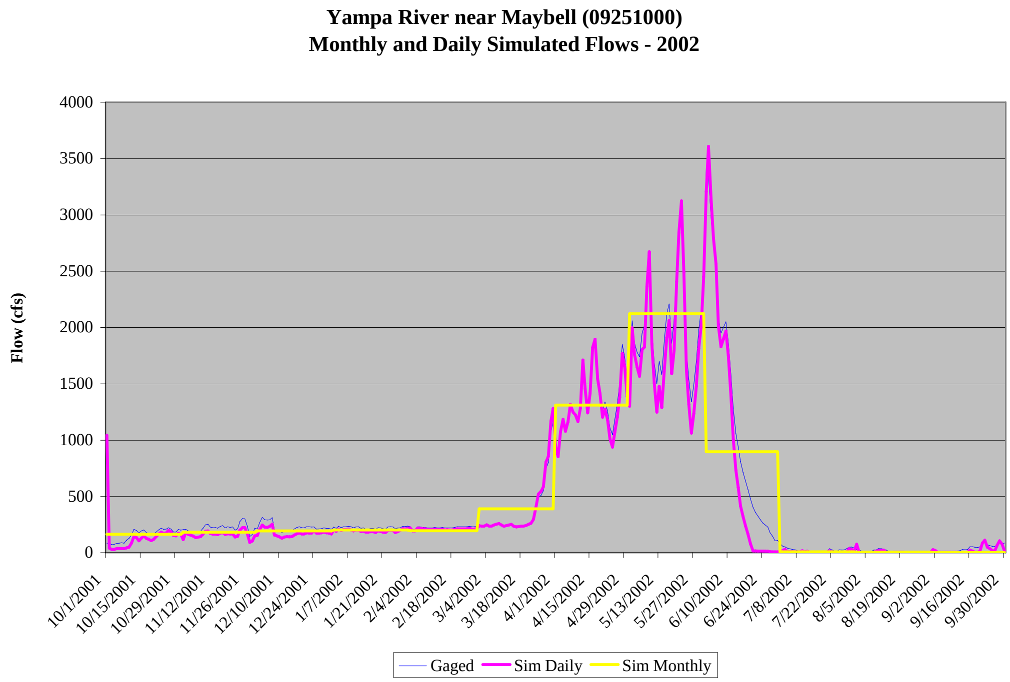


Figure E.9 Daily Baseline Comparison, Dry Year – Yampa River Near Maybell

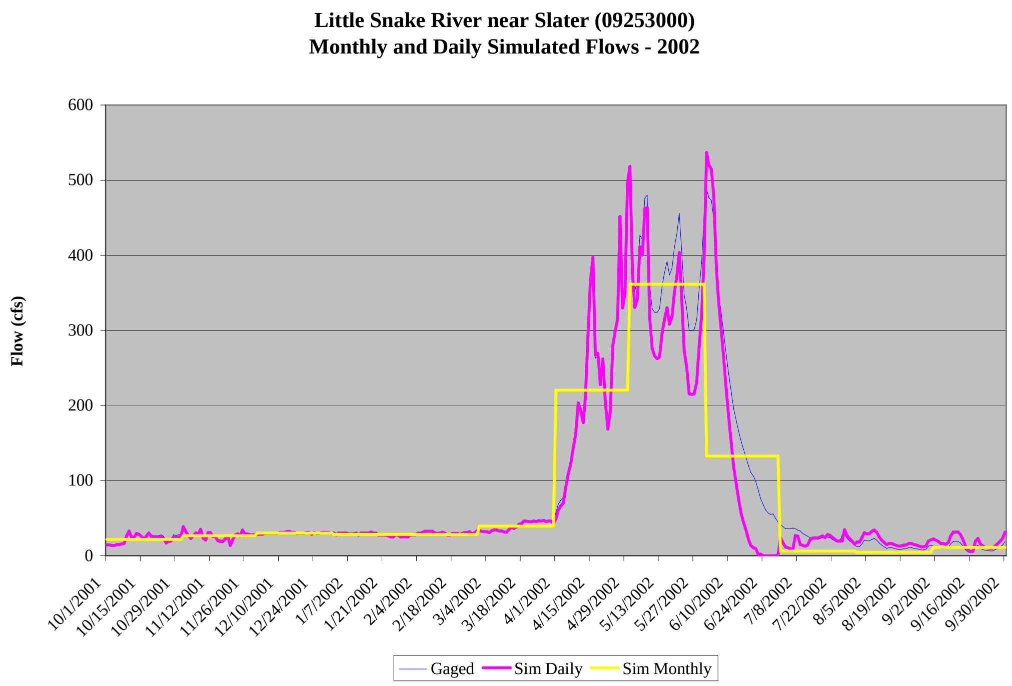


Figure E.10 Daily Baseline Comparison, Dry Year – Little Snake River Near Slater

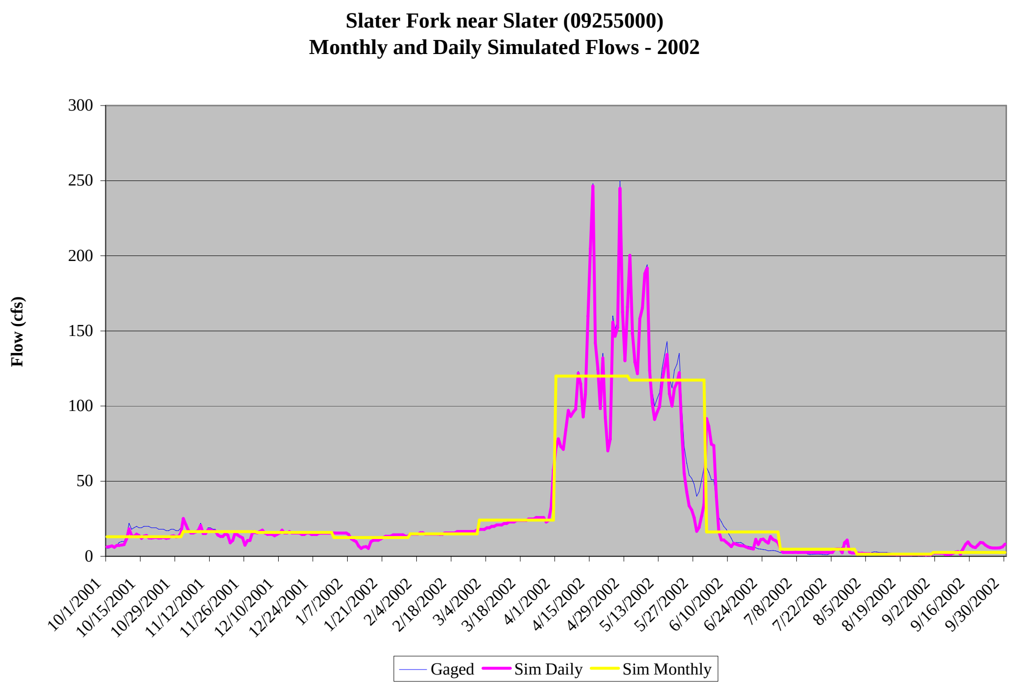


Figure E.11 Daily Baseline Comparison, Dry Year – Slater Fork Near Slater

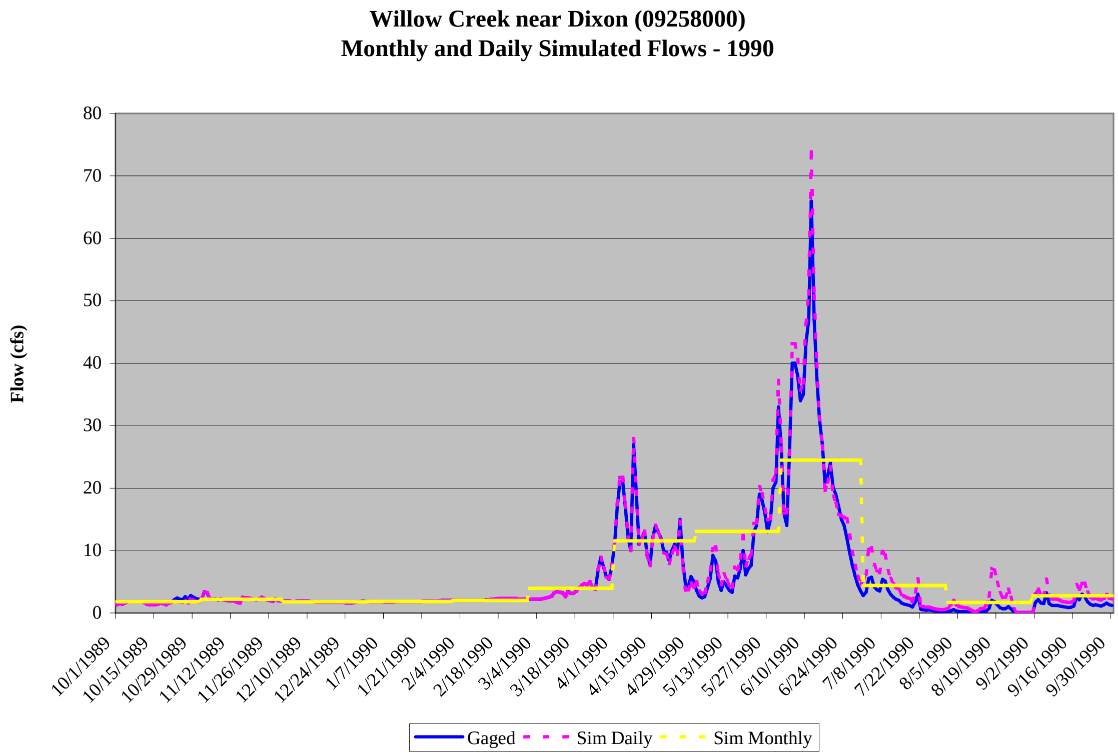


Figure E.12 Daily Baseline Comparisons – Dry Year, Willow Creek Near Dixon

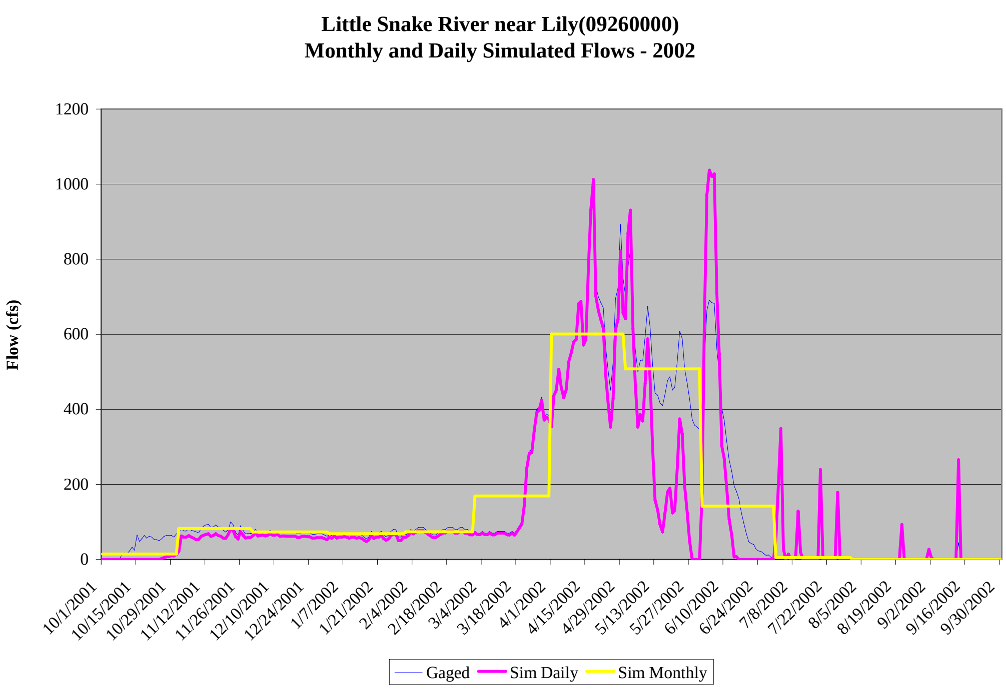


Figure E.13 Daily Baseline Comparison, Dry Year – Little Snake River Near Lily

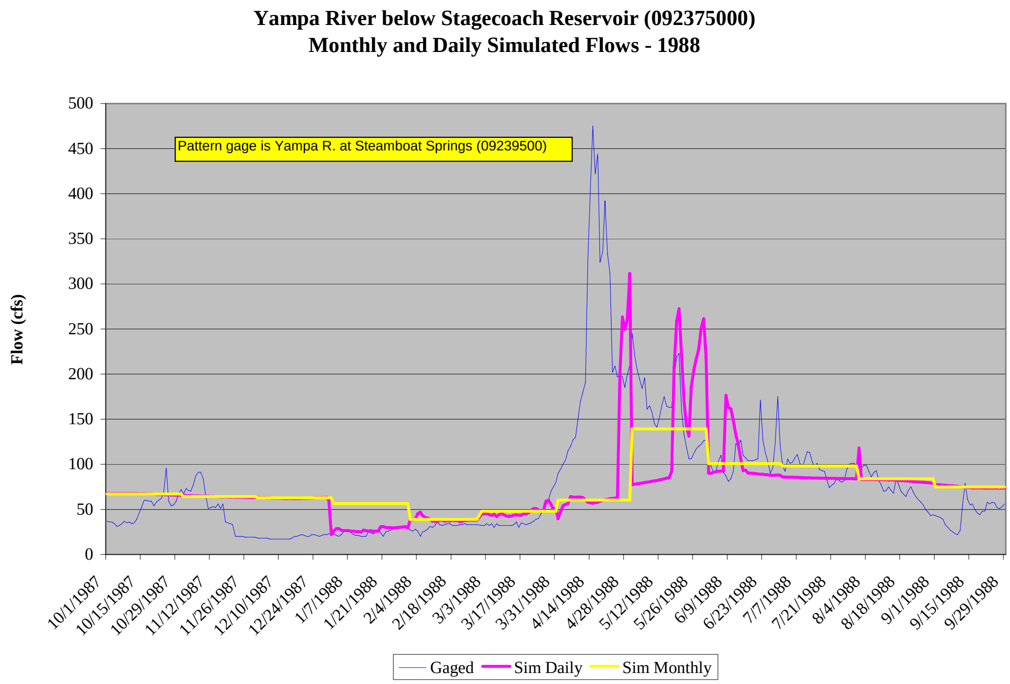


Figure E.14 Daily Baseline Comparison, Average Year – Yampa River Below Stagecoach Reservoir

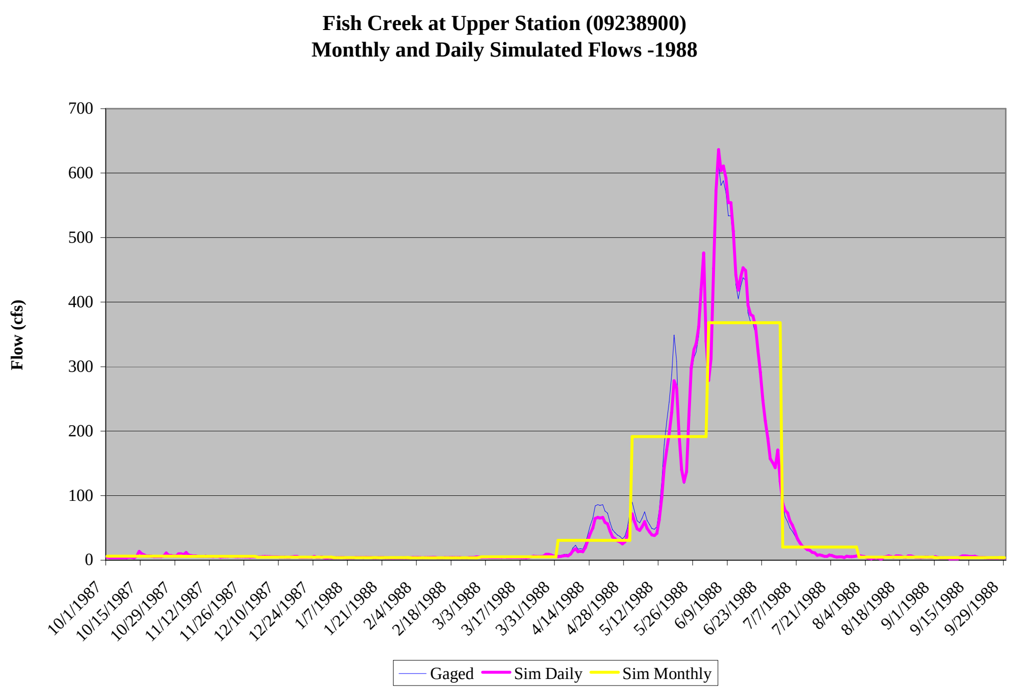


Figure E.15 Daily Baseline Comparison, Average Year – Fish Creek at Upper Station

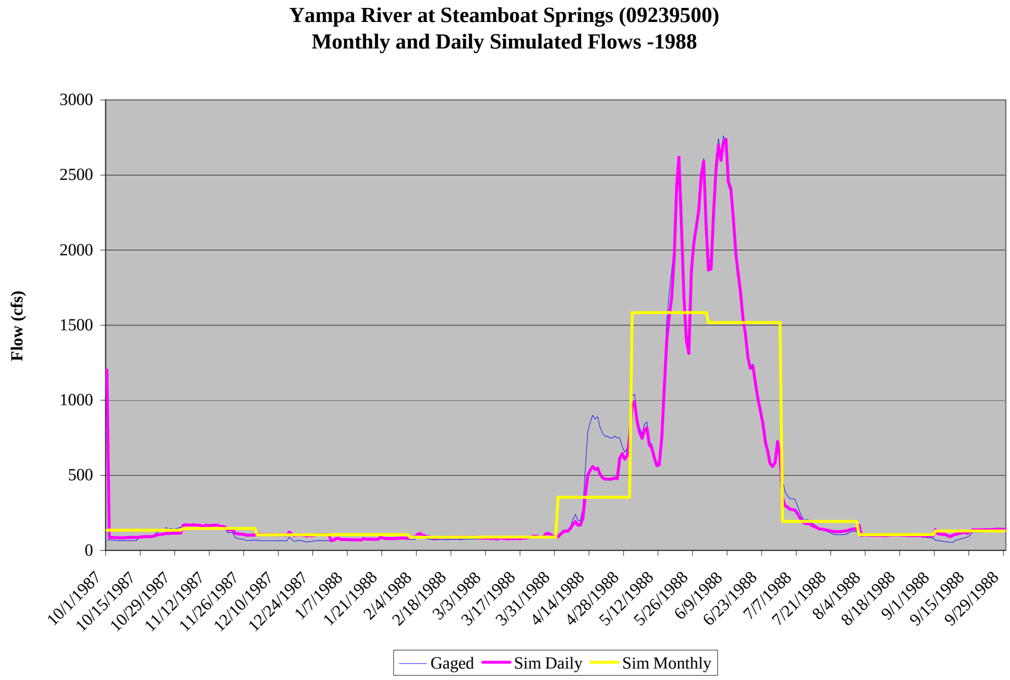


Figure E.16 Daily Baseline Comparison, Average Year – Yampa River at Steamboat Springs

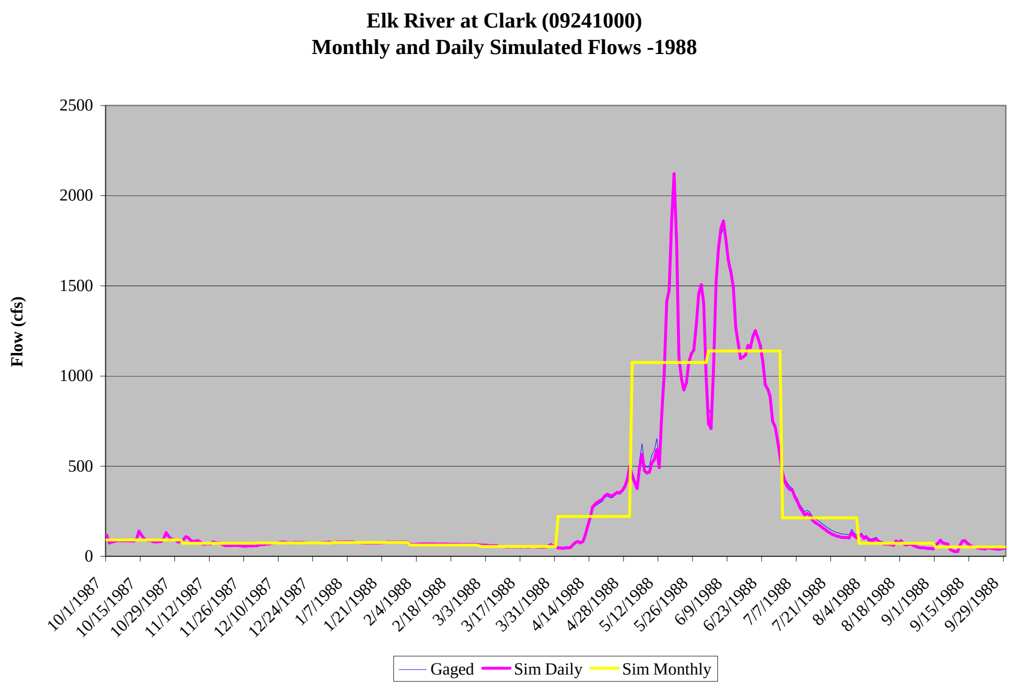


Figure E.17 Daily Baseline Comparison, Average Year – Elk River at Clark

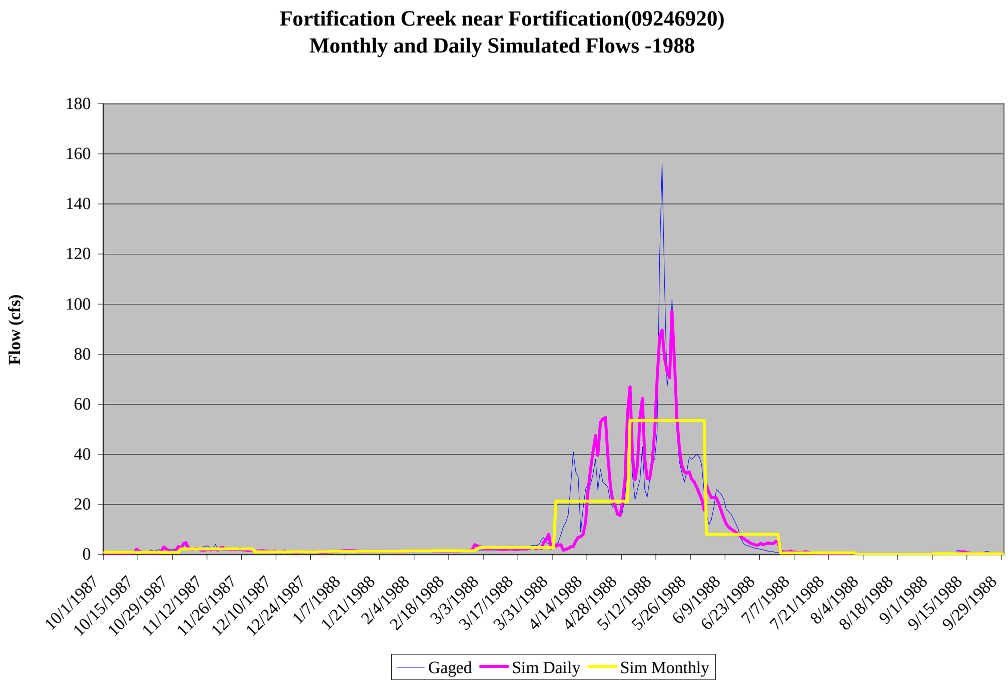


Figure E.18 Daily Baseline Comparison, Average Year – Fortification Creek Near Fortification

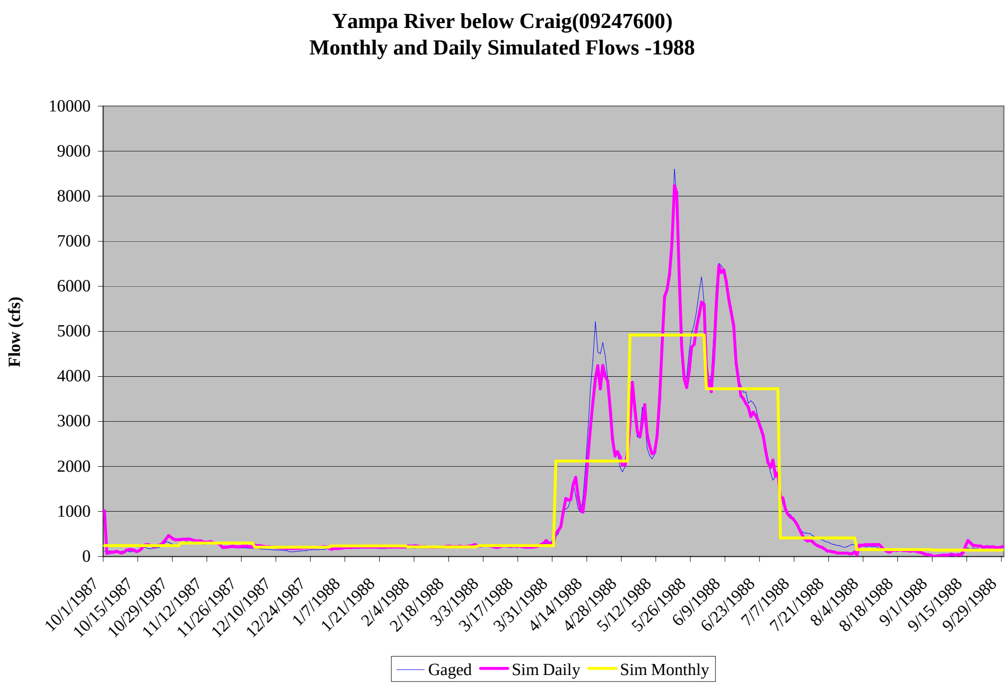


Figure E.19 Daily Baseline Comparison, Average Year – Yampa River Below Craig

Williams Fork at Mouth(09249750)
Monthly and Daily Simulated Flows -1988

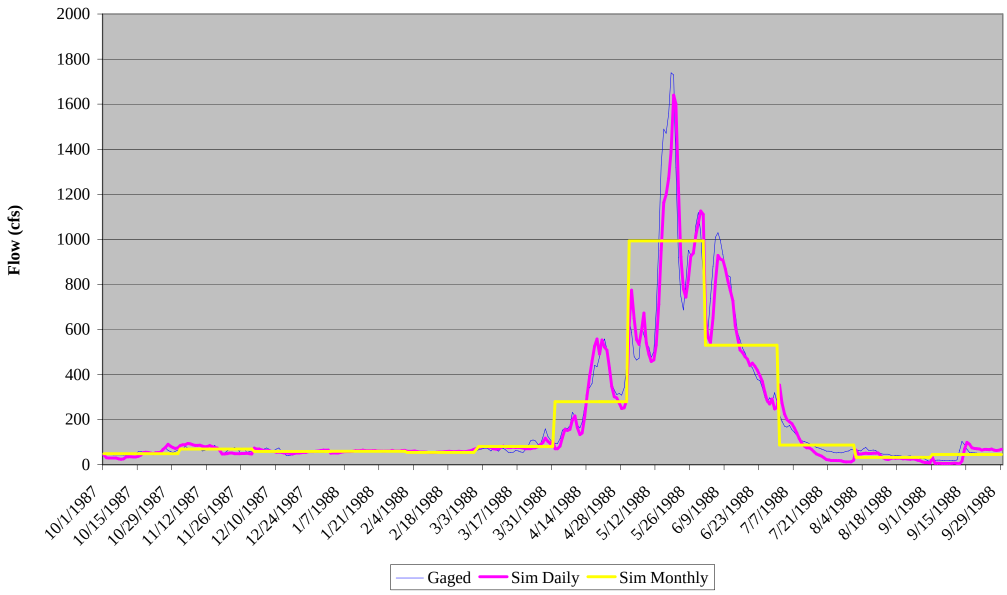


Figure E.20 Daily Baseline Comparison, Average Year – Williams Fork at Mouth

Yampa River near Maybell (09251000)
Monthly and Daily Simulated Flows -1988

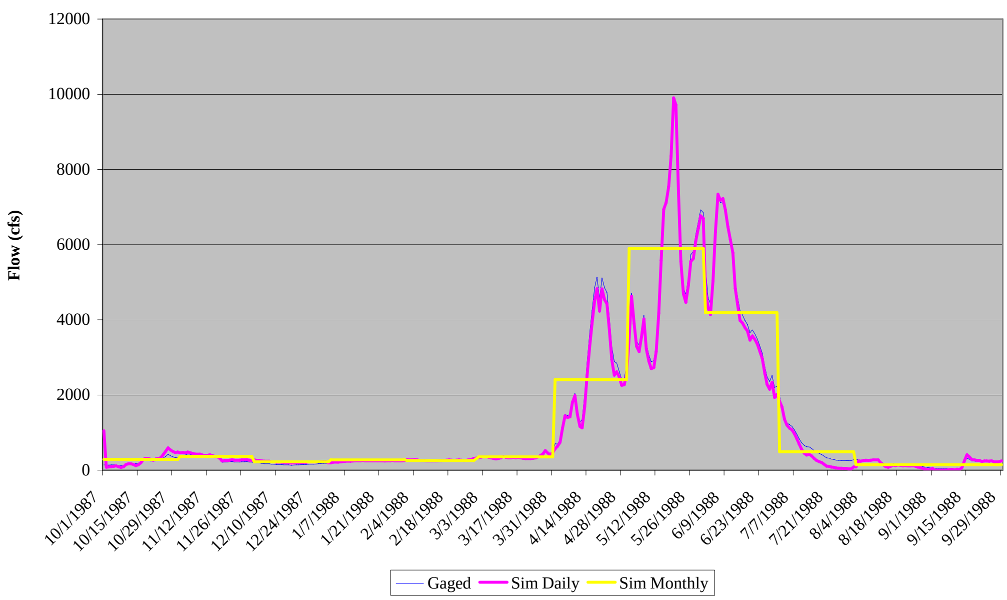


Figure E.21 Daily Baseline Comparison, Average Year – Yampa River Near Maybell

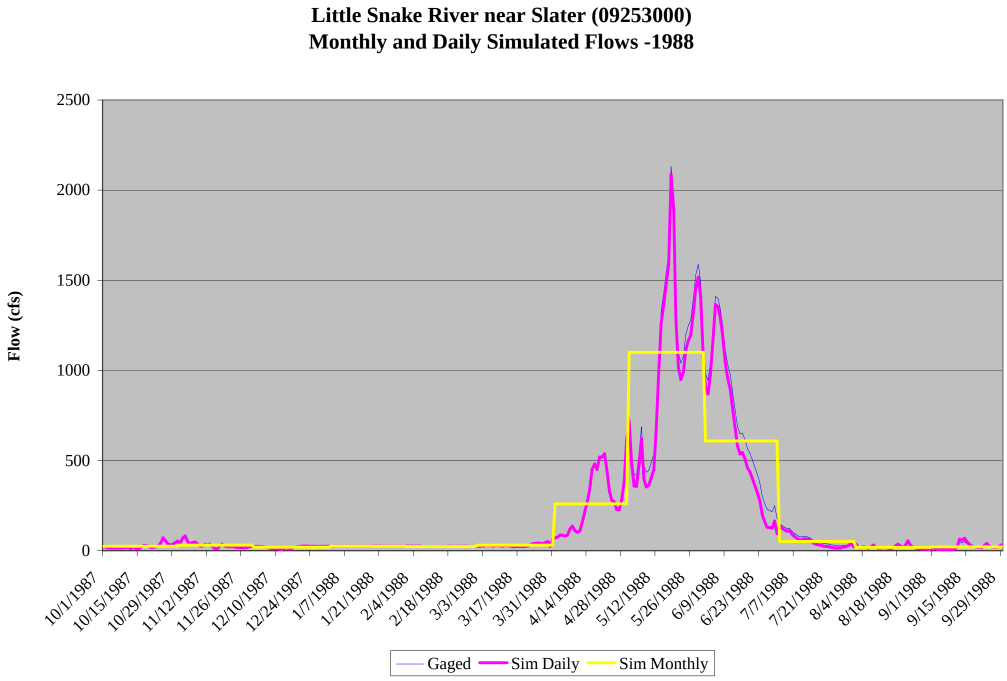


Figure E.22 Daily Baseline Comparison, Average Year – Little Snake River Near Slater

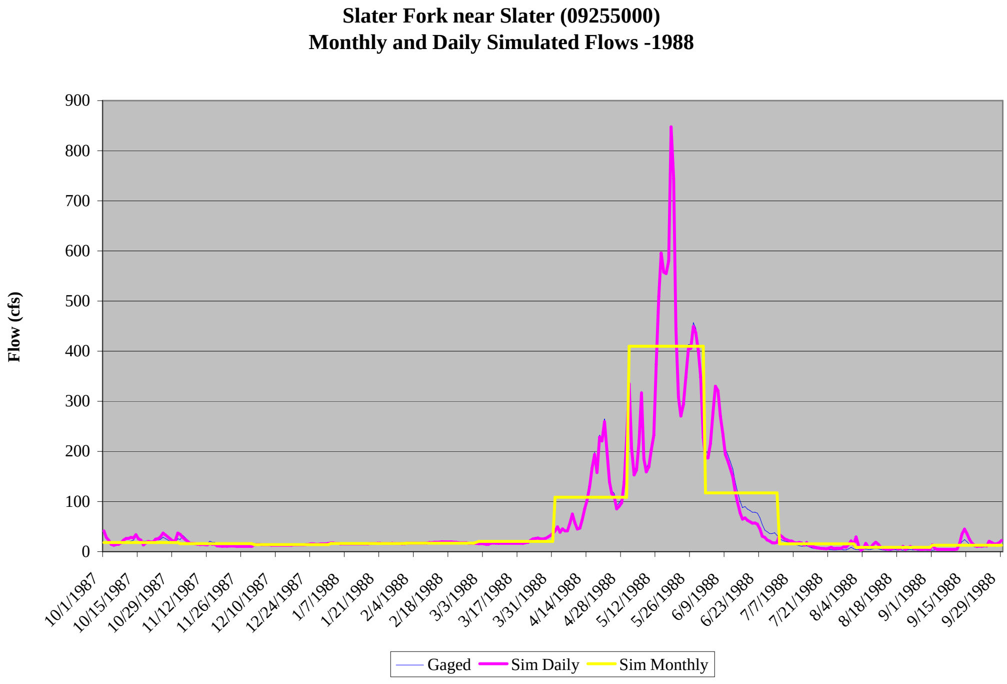


Figure E.23 Daily Baseline Comparison, Average Year – Slater Fork Near Slater

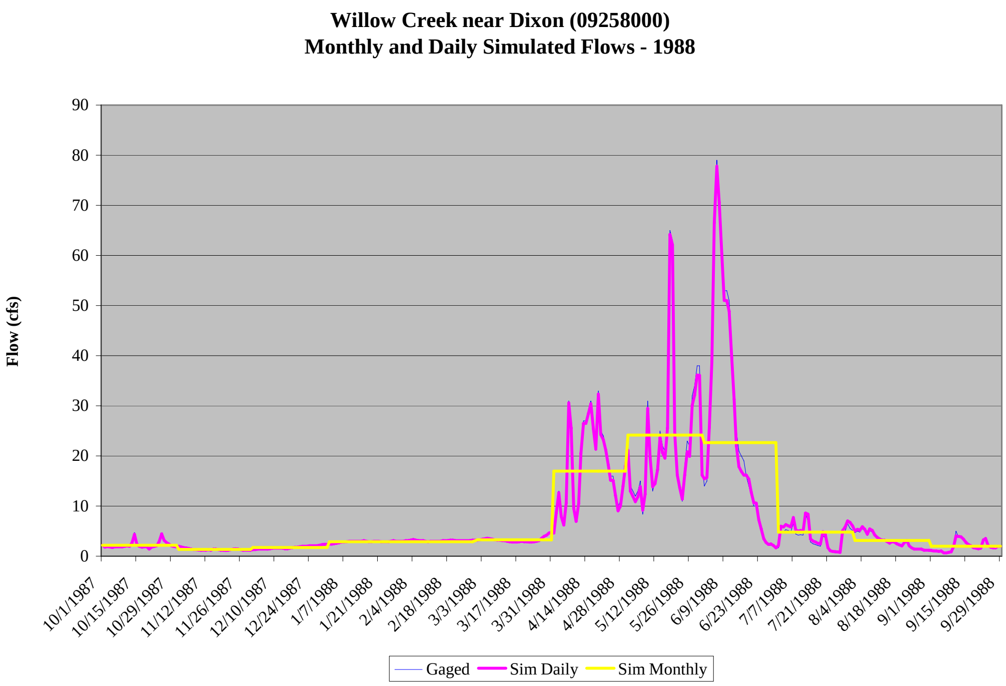


Figure E.24 Daily Baseline Comparison, Average Year – Willow Creek Near Dixon

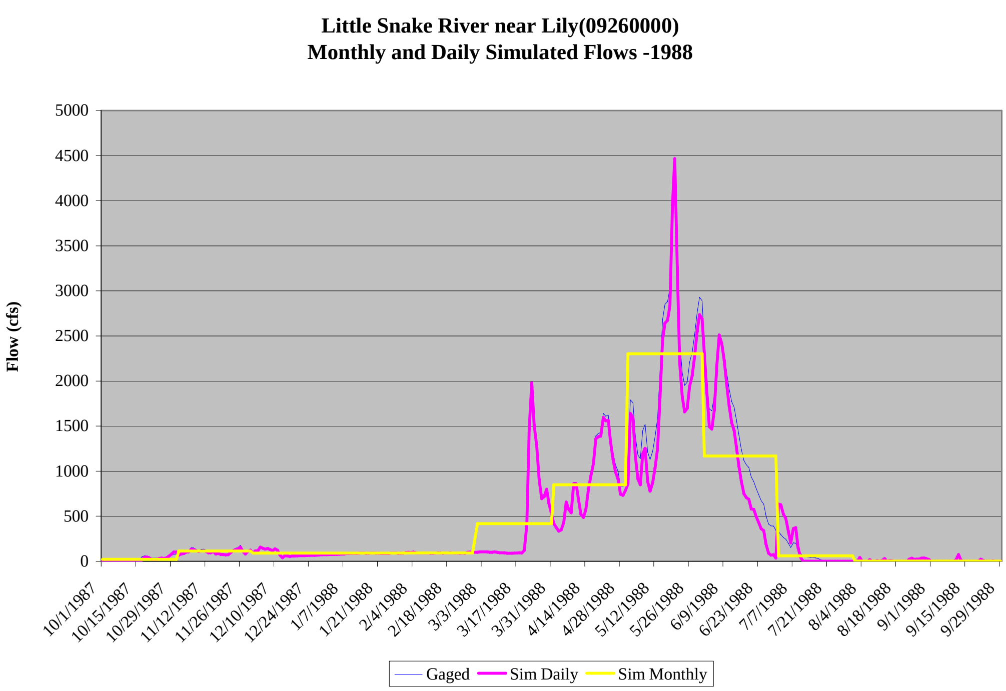


Figure E.25 Daily Baseline Comparison, Average Year – Little Snake River Near Lily

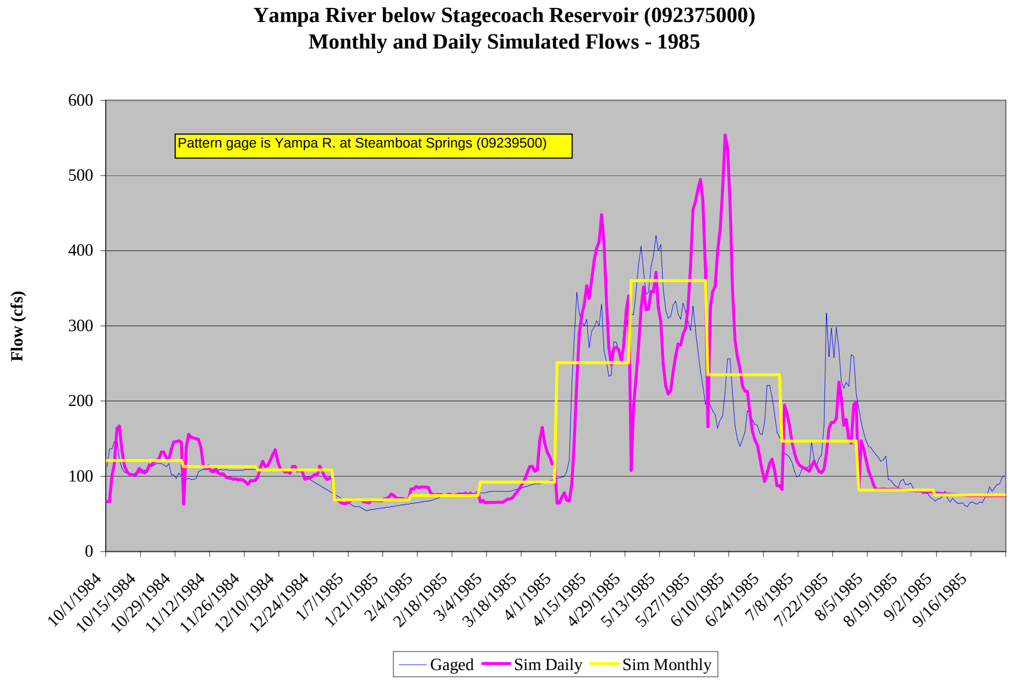


Figure E.26 Daily Baseline Comparison, Wet Year – Yampa River Below Stagecoach Reservoir

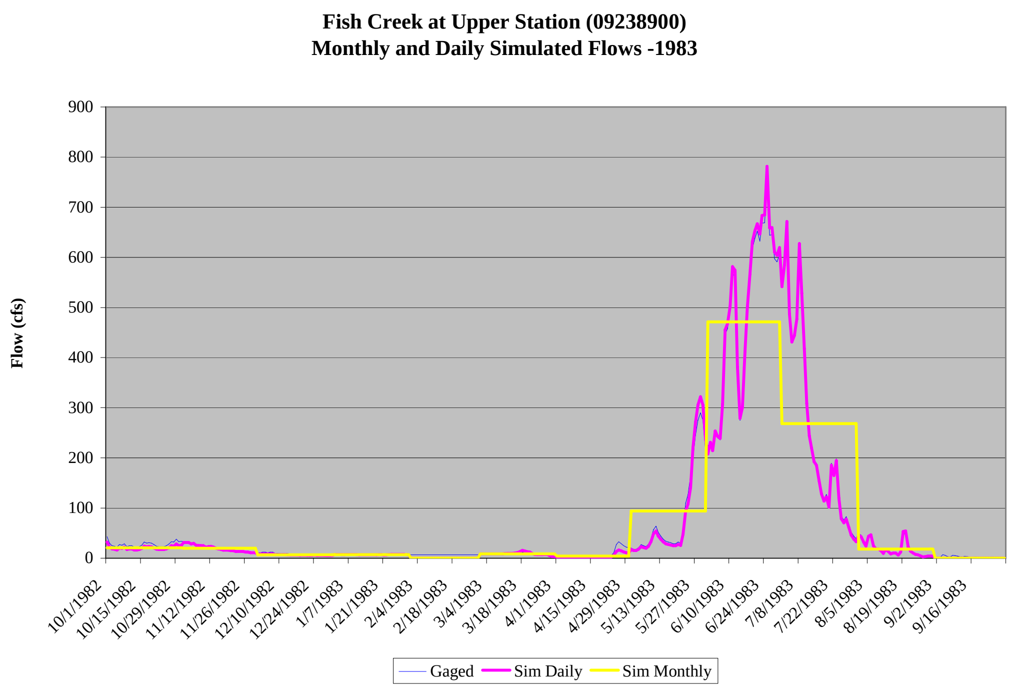


Figure E.27 Daily Baseline Comparison, Wet Year – Fish Creek at Upper Station

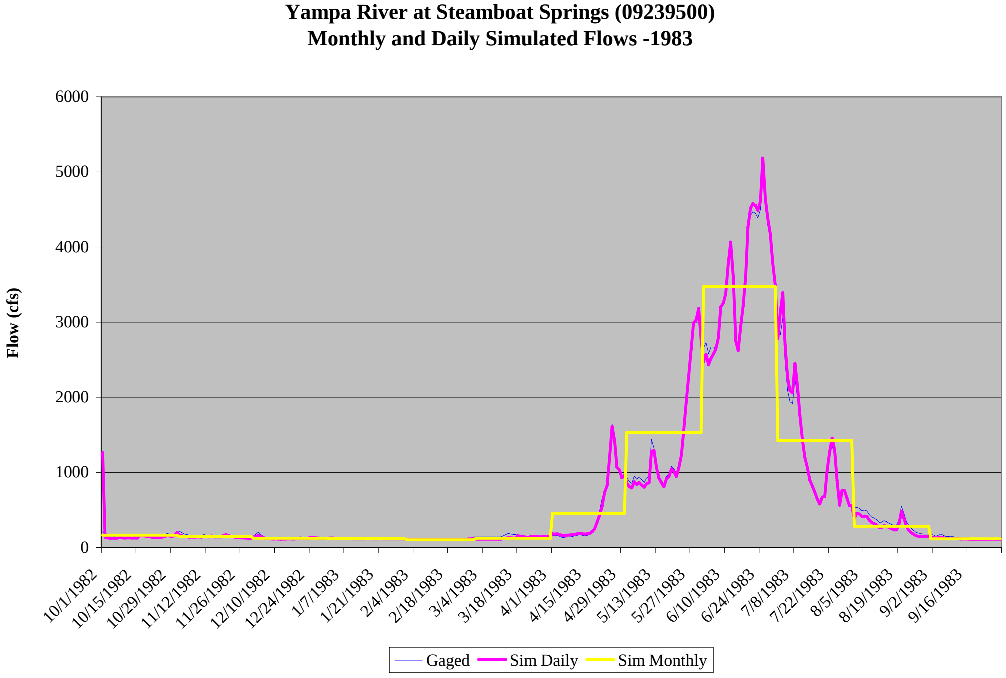


Figure E.28 Daily Baseline Comparison, Wet Year – Yampa River at Steamboat Springs

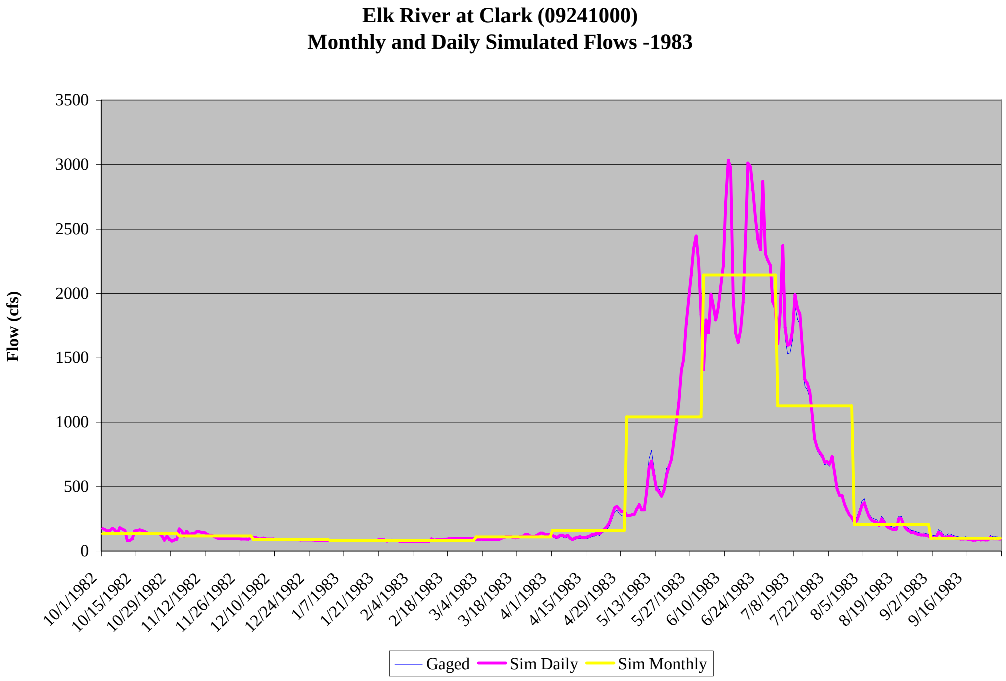


Figure E.29 Daily Baseline Comparison, Wet Year – Elk River at Clark

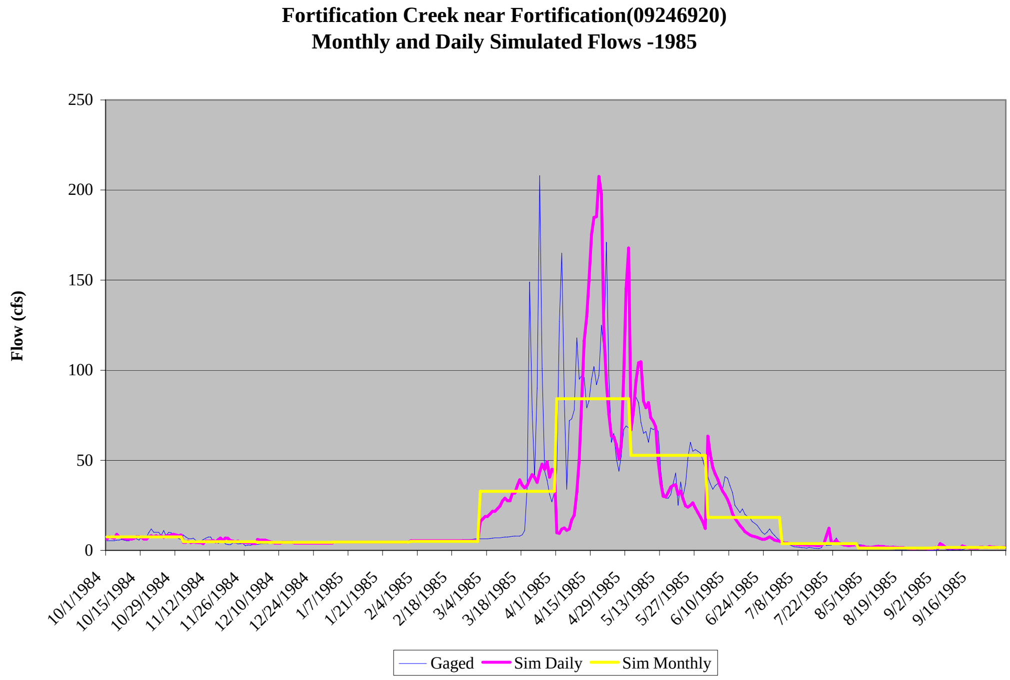


Figure E.30 Daily Baseline Comparison, Wet Year – Fortification Creek Near Fortification

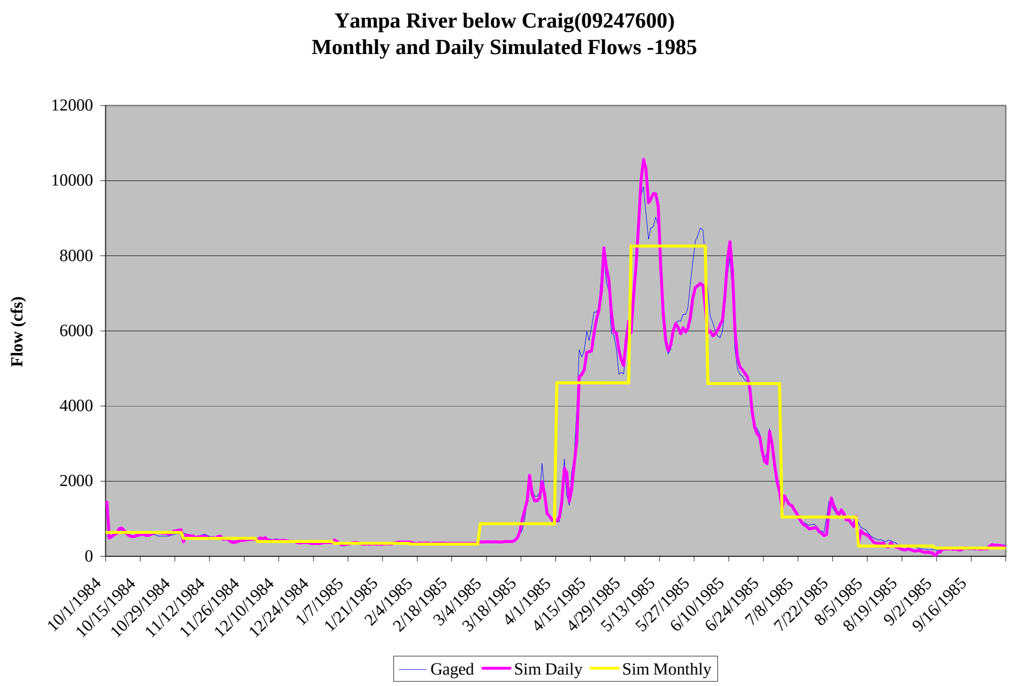


Figure E.31 Daily Baseline Comparison, Wet Year – Yampa River Below Craig

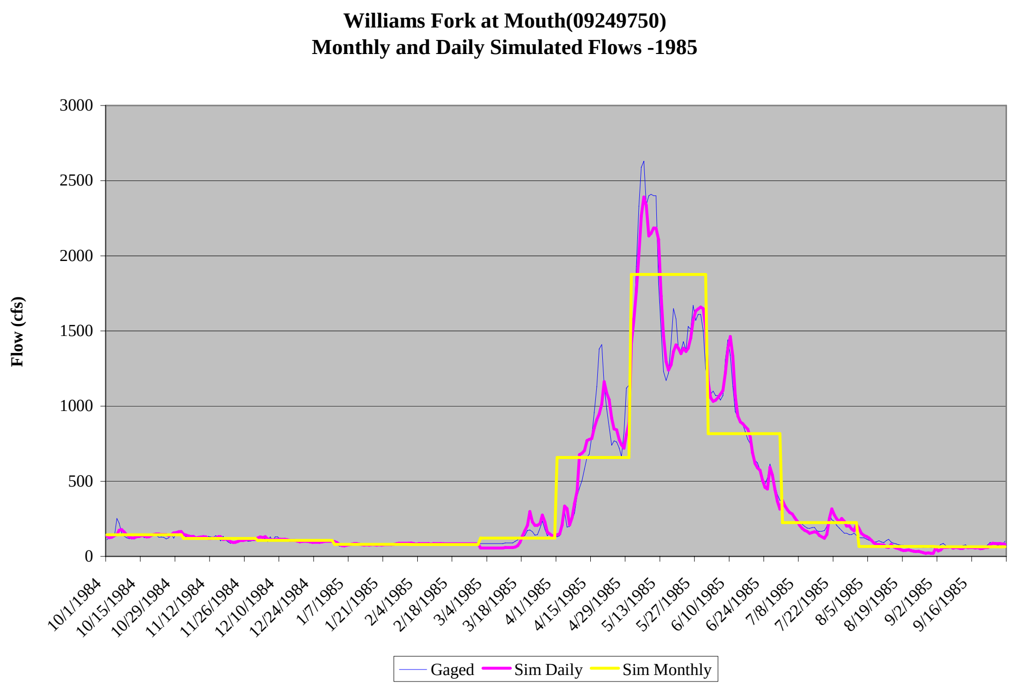


Figure E.32 Daily Baseline Comparison, Wet Year – Williams Fork at Mouth

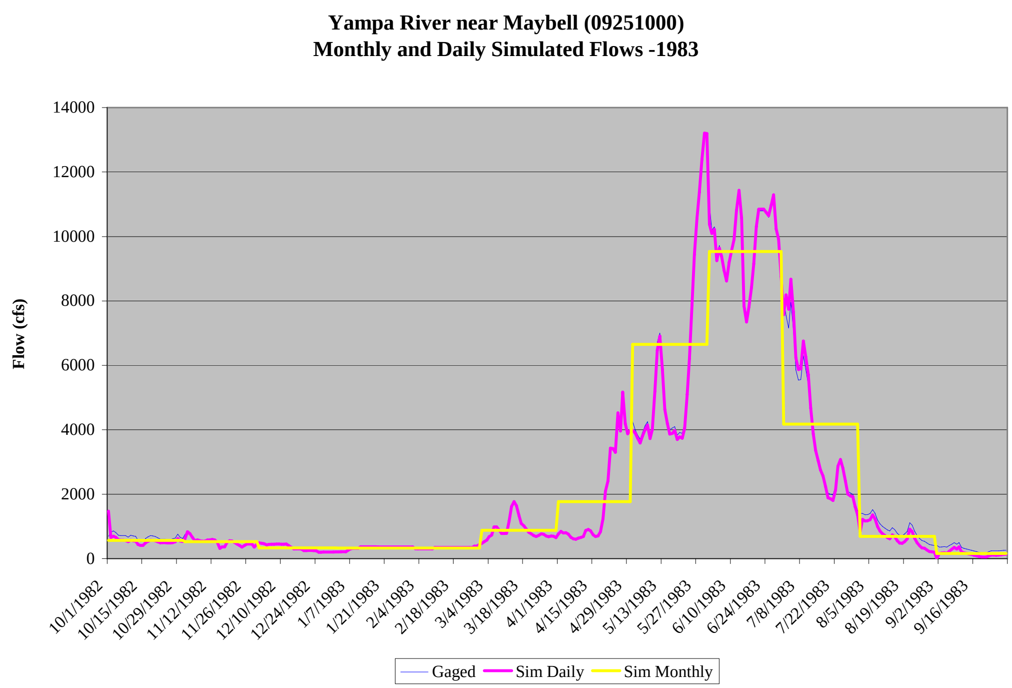


Figure 8.33 Daily Baseline Comparison, Wet Year – Yampa River Near Maybell

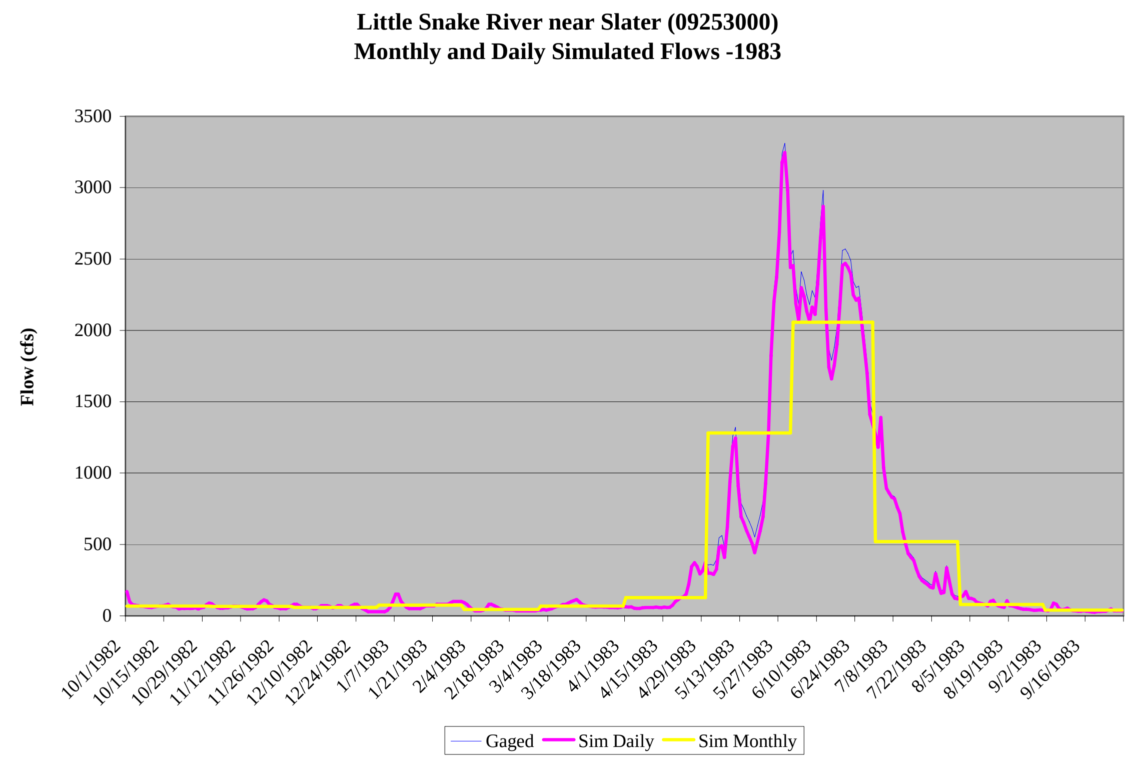


Figure E.34 Daily Baseline Comparison, Wet Year – Little Snake River Near Slater

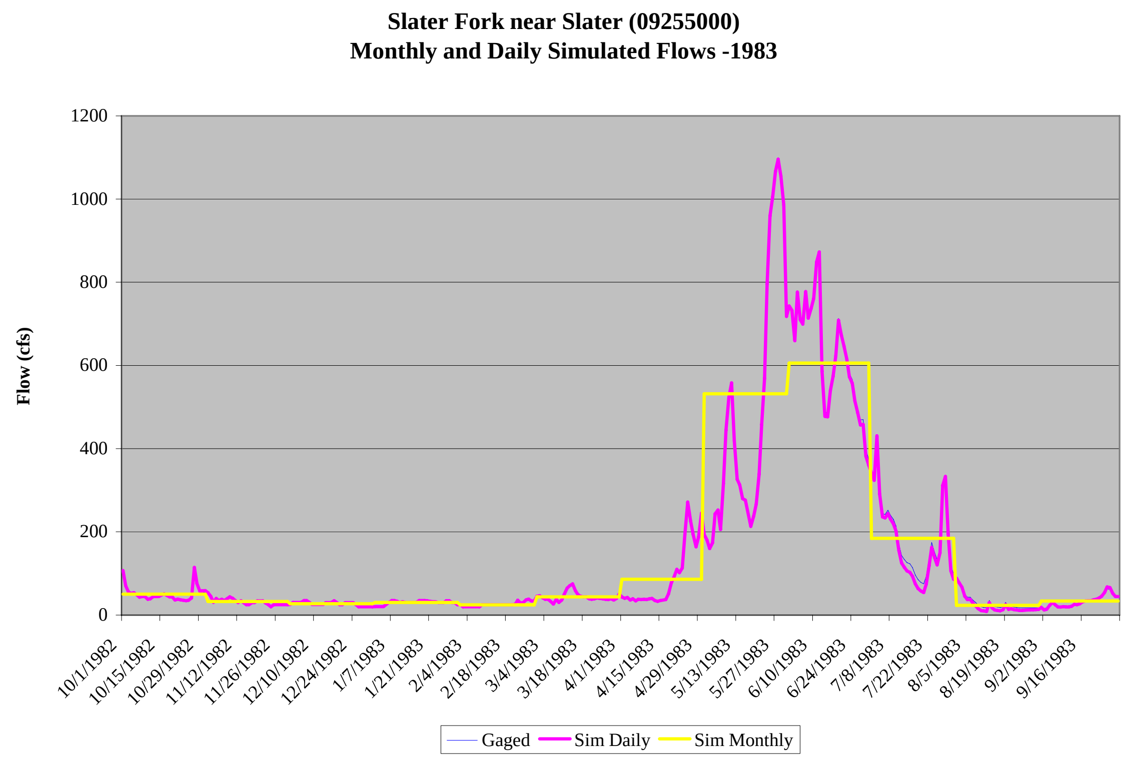


Figure E.35 Daily Baseline Comparison, Wet Year – Slater Fork Near Slater

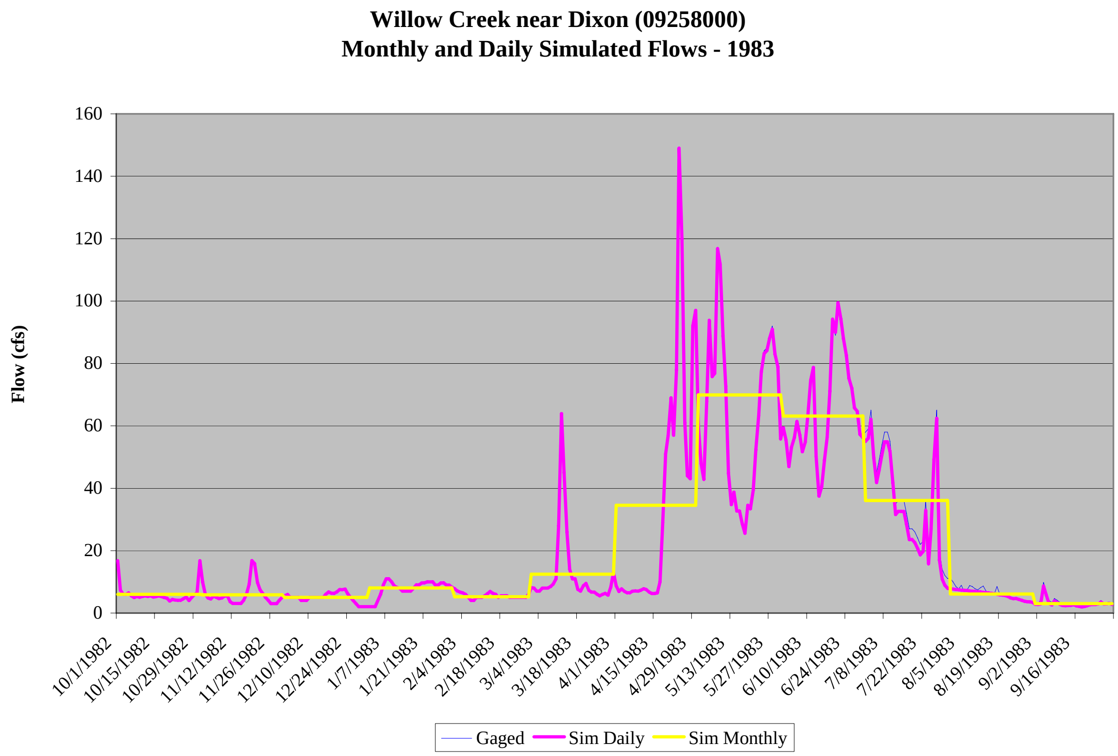


Figure E.36 Daily Baseline Comparison, Wet Year – Willow Creek Near Dixon

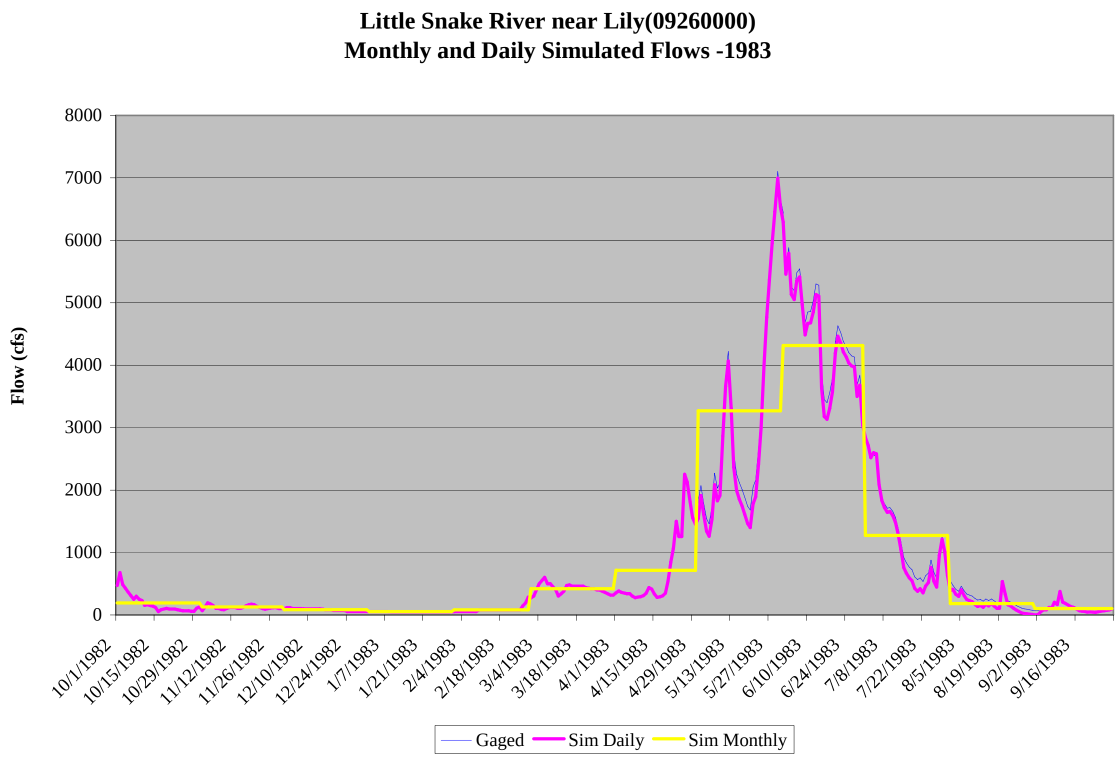


Figure E.37 Daily Baseline Comparison, Wet Year – Little Snake River near Lily

Appendix F

Historical Daily Simulation Results

Note: The Daily Baseline Model described here is an extension of the monthly Yampa model developed in 2004. When the monthly model was updated in 2009, the Daily Baseline Model was not updated.

Historical Daily Data Set

The Historical Daily Data Set is a data set that was created to run on a daily time-step. The Historical daily data set simulates the historical demands, infrastructure and projects, and administrative environment. The purpose of the Historical Daily model data set is to capture daily variations in streamflow and call regime.

The most difficult part of developing a basin model may be understanding the system. By first developing a monthly model, the system operation was investigated without developing the volume of information ultimately required for a daily model. The Historical Daily model was developed to be able to simulate large and small flow events that occur within a monthly time step. Therefore, although daily baseflows are used, other terms required for daily analysis, such as diversion demands and reservoir targets, are developed using a simplified approach.

Daily baseflows are estimated using StateMod's Daily Pattern approach. StateMod calculates each day's baseflow by disaggregating monthly baseflows using the daily pattern of flow at selected historical gages. Availability of representative "pattern gages" is critical to calibration of the daily model. The pattern gages must be available or be reliably estimated throughout the study period, and they need to exhibit runoff characteristics appropriate to the areas where they are applied to the baseflow. For this reason, presence of pattern gage records was the primary criterion in selecting a study period of 1954-2002 for the Yampa River daily model.

Historical Daily Data Set Calibration Efforts

Calibrating the Historical Daily Yampa model consisted of testing pattern gages to see which delivered the most realistic results in areas where there was not a clear choice of pattern gage. For instance, no gage in the Williams Fork basin had the requisite period of record to serve as a pattern gage. However, it was discovered that both the Little Snake River near Slater gage and the Yampa River near Maybell gage offered fairly good results. Testing both gages revealed that the Little Snake gage worked better in the upper basin, while the Yampa River near Maybell better represented timing of flows in the lower basin.

The initial daily model used the Slater Fork gage as the pattern gage for baseflow points on both Slater Creek and Willow Creek. The Willow Creek gage has a relatively long record but would have required some filling. Since the tributaries are close to each other and they are both south side tributaries, it was thought that the Slater Fork gage would adequately convey daily timing of the runoff to Willow Creek monthly flows. When the daily model was executed this way, it was discovered that Slater Fork's timing differs significantly from Willow Creek's. The approach then taken was to fill the Willow Creek gage record, and use it as the pattern gage on Willow Creek. The filled portion of the record has errors in it, but the compromise allowed the daily model to take advantage of nearly 40 years of data that worked very well as a pattern within the tributary basin.

Historical Daily Simulation Results

Simulation of the Historical Daily Yampa River model is considered good, with most streamflow gages deviating a few percent from historical values on an average annual basis. Discrepancies between historical and simulated flow are generally larger in the daily model than in the monthly model. Shortages are also greater in the daily model than the monthly model, and it is notable that there are some gages for which, although there are diversion shortages within a month above the gage, simulated gage flow is lower than historical in the same month. This may be due to inaccurate distribution of baseflow across the month, inaccurate distribution of demand across the month, or both. Simulated reservoir contents exhibit more or less the same characteristics in the daily model as the monthly model (see Section 7.4).

Water Balance Results

Table E.1 summarizes the water balance for the Historical Daily Yampa River model for the calibration period (1975-2002). Following are observations based on the summary table:

- Surface water inflow to the basin averages 2.03 million acre-feet per year, and stream outflow averages 1.83 million acre-feet per year.
- Annual diversions amount to approximately 484,000 acre-feet on average.
- Approximately 160,000 acre-feet per year is consumed in the Historical Daily simulation. Note that this value is representative of the basin-wide (both Colorado and Wyoming) consumptive use and includes crop consumptive use, municipal and industrial consumptive use, reservoir evaporation, and 100 percent of exports from the basin.
- The column labeled “Inflow – Outflow” represents the net result of gain (inflow, return flows, and negative change in reservoir and soil moisture contents) less outflow terms (diversions, outflow, evaporation, and positive changes in storage). The small values are due to rounding on a daily basis, and indicate that the model correctly conserves mass.

Table F.1
Average Annual Water Balance for Historical Daily Simulation (af/yr)

Month	Stream Inflow	Return	From Soil Moisture	Total Inflow	Diversions	Resvr Evap	Stream Outflow	Resvr Change	To Soil Moisture	Soil Moisture Change	Total Outflow	Inflow - Outflow	CU
OCT	37,697	15,796	715	54,208	15,920	772	38,067	-1,266	1,332	-617	54,208	0	4,211
NOV	33,068	7,384	0	40,452	4,821	-26	34,513	1,135	258	-258	40,443	8	1,473
DEC	27,889	5,811	0	33,700	4,542	-284	28,614	829	187	-187	33,700	0	1,529
JAN	28,096	4,979	0	33,075	4,610	-314	28,157	622	133	-133	33,075	0	1,548
FEB	32,610	3,686	0	36,296	4,117	-74	31,829	423	105	-105	36,294	2	1,415
MAR	83,317	3,668	0	86,985	4,895	364	80,658	1,072	143	-143	86,989	-4	1,856
APR	238,270	6,315	637	245,222	12,474	915	228,781	2,415	1,474	-837	245,222	0	4,158
MAY	636,373	39,099	1,538	677,009	87,025	1,719	585,918	809	11,299	-9,761	677,009	0	20,420
JUN	620,716	83,392	1,784	705,891	158,270	2,456	544,645	-1,263	12,433	-10,649	705,892	0	39,192
JUL	205,584	69,691	6,337	281,611	109,936	2,384	165,253	-2,297	3,089	3,248	281,612	-1	39,745
AUG	56,634	33,692	11,420	101,745	47,400	1,767	41,357	-196	862	10,558	101,746	-1	30,483
SEP	33,050	22,872	5,406	61,327	29,871	1,519	25,269	-737	1,629	3,777	61,328	-1	14,895
AVG	2,033,303	296,383	27,836	2,357,522	483,880	11,197	1,833,061	1,545	32,943	-5,107	2,357,519	4	160,926

Note: Consumptive Use (CU) = Diversion (Divert) * Efficiency + Reservoir Evaporation (Evap)

Streamflow Results

Table E.2 summarizes the average annual streamflow for water years 1975 through 2002, as estimated in the Historical Daily simulation. It also shows average annual values of actual gage records for comparison. Both numbers are based only on years for which gage data are complete. Calibration based on streamflow simulation is generally good; with the exception of the gage below Stagecoach Reservoir, all gages are within a few percentage points of actual on an average annual basis. The difficulty in simulating the Stagecoach Reservoir gage is probably related to the inexact disaggregation of the demands for which the reservoir is releasing. These include the power demand at the reservoir, as well as municipal and industrial demands at Mt. Werner/Steamboat Springs and Craig, respectively.

Comparisons of historical and simulated daily flows are illustrated in Figures E.1 through E.36 for three selected years for a sampling of gages which includes both pattern and non-pattern gages. The selected years represent wet (1983 or 1985 depending on gage availability), average (1988), and dry (2002, 1977, or 1990 depending on gage availability) years in the Yampa Basin.

The hydrographs indicate that the wet and normal years simulate better than dry years. The daily model shows more positive annual differences between historical and simulated gages than the monthly model, that is, the simulated gage value is lower than the historical gage. The reason for this is not clearly understood, but may be related to the daily model's ability to allow junior diverters to capture peak flows, and the higher consumptive use in the daily model than the monthly model. In the daily modeling pilot project, gage values had more of a tendency to be lower than historical, compared with the monthly model, but the discrepancies were smaller than in this model. Thus the tendency might also be related to other differences between the pilot daily model and this model, namely, use of variable rather than constant efficiency, or calibrating with Calculated irrigation demand rather than historical irrigation demand.

In the daily modeling efforts, the release to target rule used to mimic hydropower operations uses a monthly storage target. At this time, there appears to be a discrepancy between the releases to this monthly target on the first day of each simulated year (October 1) compared to the releases to this monthly target for the remaining months in the year. This is noticeable at any of the mainstem gages downstream of Stagecoach Reservoir. It is important to note that this "spike" flow does not affect overall results or usefulness of the model. It is expected that future StateMod code enhancements will correct this discrepancy.

Table F.2
Historical and Simulated Average Annual Streamflow Volumes (1975-2002)
Historical Daily Simulation (acre-feet/year)

Gage ID	Historical	Simulated	Historical minus Simulated Volume	Historical minus Simulated Percent	Gage Name
9236000	29,633	29,637	-4	0	Bear River Near Toponas
9237500	59,770	55,825	3,944	7	Yampa River Below Stagecoach Reservoir
9238900	44,492	44,643	-151	0	Fish Creek At Upper Station
9239500	322,547	316,421	6,126	2	Yampa River At Steamboat Springs
9241000	231,396	230,971	426	0	Elk River At Clark
9244410	834,379	824,504	9,876	1	Yampa River Below Diversion near Hayden
9245000	42,324	42,324	0	0	Elkhead Creek Near Elkhead
9245500	*No gage during calibration period*			0	North Fork Elkhead Creek
9246920	7,957	8,132	-174	-2	Fortification Creek near Fortification
9247600	893,891	878,116	15,776	2	Yampa River Below Craig
9249000	*No gage during calibration period*			0	East Fork Of Williams Fork
9249200	28,073	28,067	5	0	South Fork Of Williams Fork
9249750	154,433	151,186	3,247	2	Williams Fork At Mouth
9251000	1,126,118	1,103,973	22,145	2	Yampa River Near Maybell
9253000	168,110	168,176	-66	0	Little Snake River Near Slater
9255000	60,923	60,360	564	1	Slater Fork Near Slater
9255500	39,077	38,679	398	1	Savery Creek at Upper Station
9256000	85,981	85,328	653	1	Savery Creek near Savery
9257000	378,895	377,412	1,483	0	Little Snake River Near Dixon
9258000	7,930	8,002	-71	-1	Willow Creek Near Dixon
9260000	409,932	399,172	10,760	3	Little Snake River Near Lily
9260050	1,531,326	1,496,533	34,793	2	Yampa River At Deerlodge Park

Diversion Results

Table E.3 summarizes the average annual simulated diversions, by tributary or sub-basin, compared to historical diversions for water years 1975 through 2002. On a basin-wide basis, average annual diversions differ from historical diversions by about 5.2 percent in the daily calibration run, an increase of 3.6 percent relative to the monthly model. As in the monthly model, the Fortification Creek basin is the most shorted. Shortages in the Little Snake River basin are notably larger in the daily model than in the monthly model, which could be attributable to the time distribution of either baseflows or demand.

In monthly modeling efforts, shortages in a basin are typically associated with gages that overestimate flows. This happens because it is impossible to spatially distribute baseflows correctly in all time steps, using a single disaggregation rule. Sometimes, upstream baseflows are too small, in which case the water "misses" the opportunity to be diverted, but enters the stream above the gage, resulting in extra water in the gage. Or, upstream diverters are shorted in order to provide flow to a downstream senior right below the gage, because the baseflow below the gage was underestimated. In this case, the bypassed water enlarges the gage flow, relative to historical. In the daily model, it appears that diversion shortages and low gages can occur at the same time, at least in an annual analysis.

Table F.3
Historical and Simulated Average Annual Diversions by Sub-basin (1975-2002)
Historical Daily Simulation (acre-feet/year)

Tributary or Sub-basin	Historical	Simulated	Historical minus Simulated	
			Volume	Percent
Upper Yampa River (Stagecoach Reservoir gage and above)	85,042	79,586	5,456	6.4%
Yampa River (Stagecoach Reservoir to Elk River)	41,131	39,558	1,573	3.8%
Elk River	37,870	37,023	847	2.2%
Trout Creek	12,848	12,737	111	0.9%
Elkhead Creek	7,128	6,670	458	6.4%
Fortification Creek	8,140	6,952	1,188	14.6%
Yampa River (Elk River to Craig gage)	69,642	69,169	473	0.7%
Williams Fork	31,978	29,781	2,197	6.9%
Yampa River (Williams Fork to Little Snake River)	61,535	60,352	1,183	1.9%
Upper Little Snake River (above Muddy Creek)	95,470	88,058	7,412	7.8%
Lower Little Snake River (Muddy Creek and below)	47,608	42,252	5,356	11.3%
Yampa River below Little Snake River	12,004	11,972	32	0.3%
Basin Total	**510,400**	**484,100**	**26,300**	**5.2%**

Reservoir Results

Figures F.37 through F.41 (located at the end of this chapter) present reservoir EOM contents estimated by the Historical Daily model simulation, compared to historical observations at selected reservoirs. Simulated reservoir end-of-month contents using a daily time-step are very close to simulations using a monthly time-step. The issues identified in Section 7.4.4 are valid on a daily time-step.

Consumptive Use Results

Table E.4 compares StateCU-estimated crop consumptive use with StateMod estimate of crop consumptive use for explicit structures, aggregate structures, and basin total. Consumptive use in the Wyoming portion of the Yampa basin is not included here, nor is consumptive use attributable to municipal, industrial, or transbasin diversions included. As shown, both explicit and aggregate structure consumptive use match StateCU results very well. Historical diversions are used by StateCU to estimate supply-limited (actual) consumptive use. The less than 0.5 percent difference, basinwide within Colorado, is consistent with the overall basin diversion shortages simulated by the model. It appears to be a better replication of consumptive use than that provided by the monthly model (see Table 7.5).

Table F.4
Average Annual Crop Consumptive Use Comparison (1975-2002)

Comparison	StateCU Results (af/yr)	Calibration Run Results (af/yr)	% Difference
Explicit Structures	58,780	58,971	-.32
Aggregate Structures	34,685	34,877	-.55
Colorado Total	93,465	93,848	-.41

Yampa River below Stagecoach Reservoir (092375000)
Gaged and Simulated Daily Flows - 1985

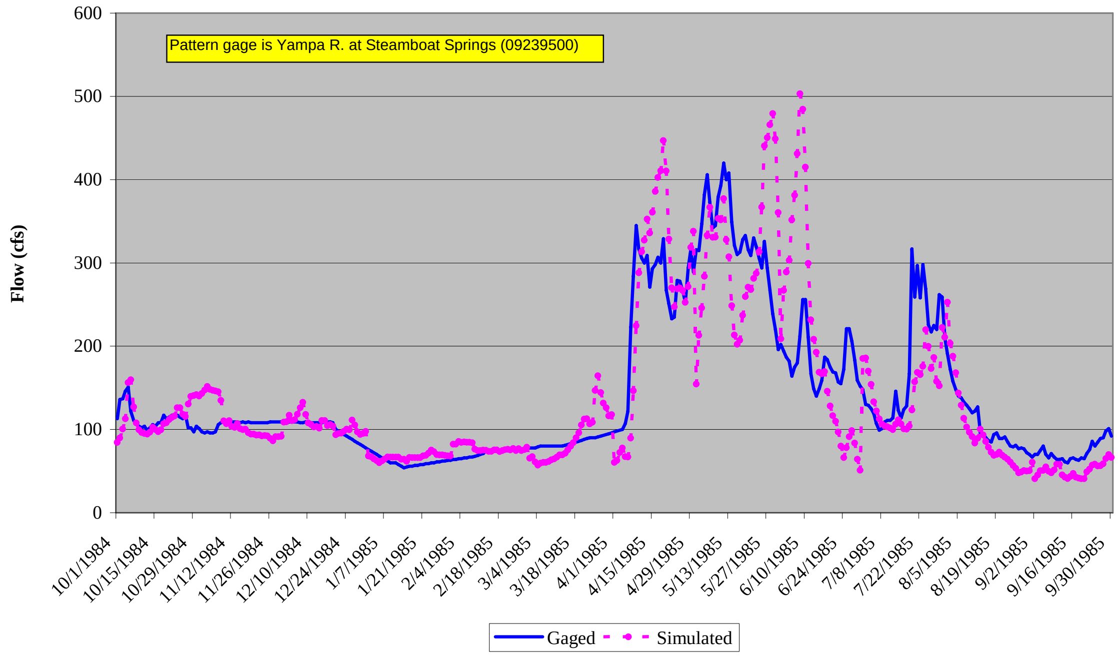


Figure F.1 Historical Daily Comparison, Wet Year – Yampa River Below Stagecoach Reservoir

Fish Creek at Upper Station (09238900)
Gaged and Simulated Daily Flows - 1983

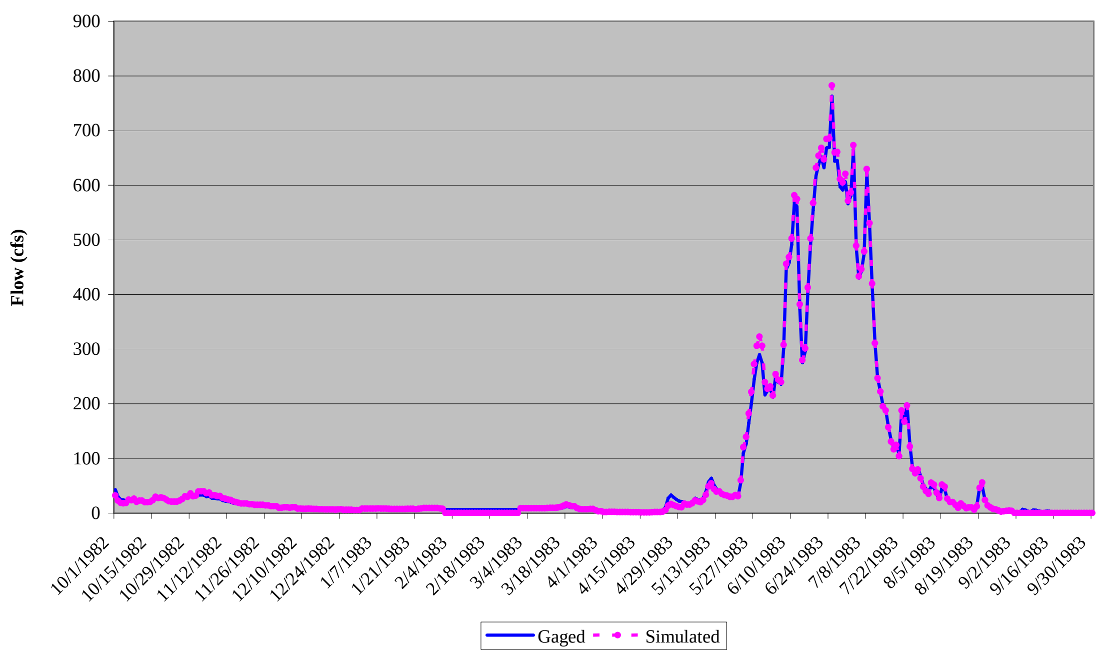


Figure F.2 Historical Daily Comparison, Wet Year – Fish Creek at Upper Station

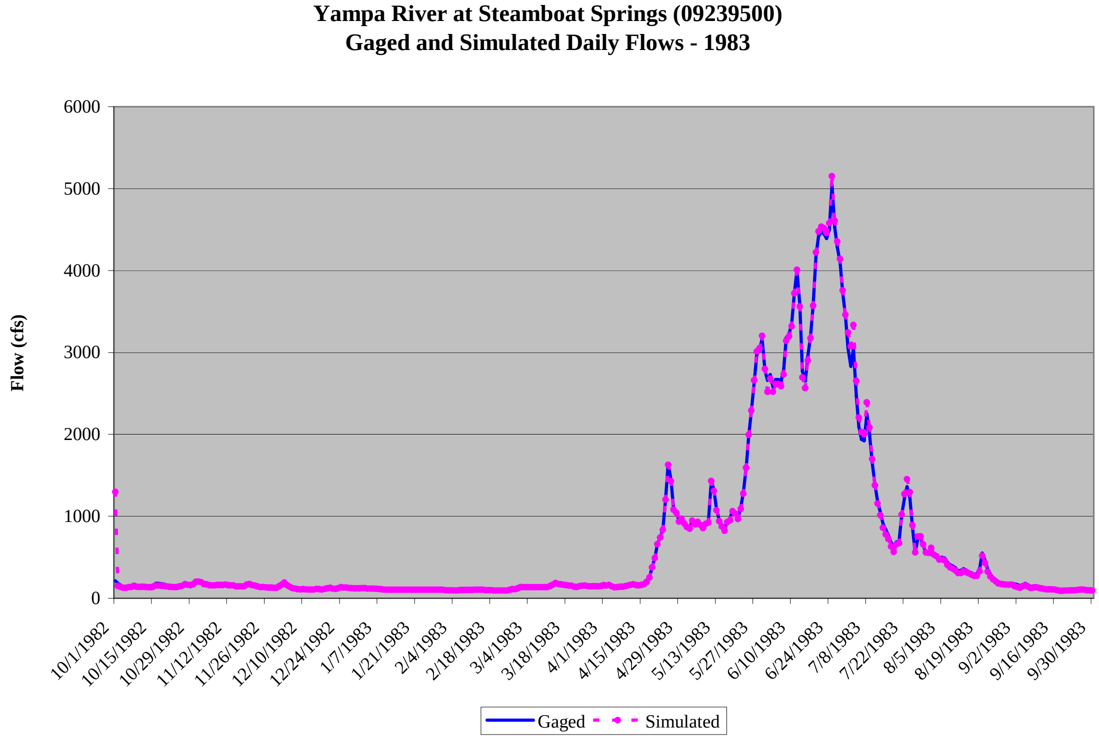


Figure F.3 Historical Daily Comparison, Wet Year – Yampa River at Steamboat Springs

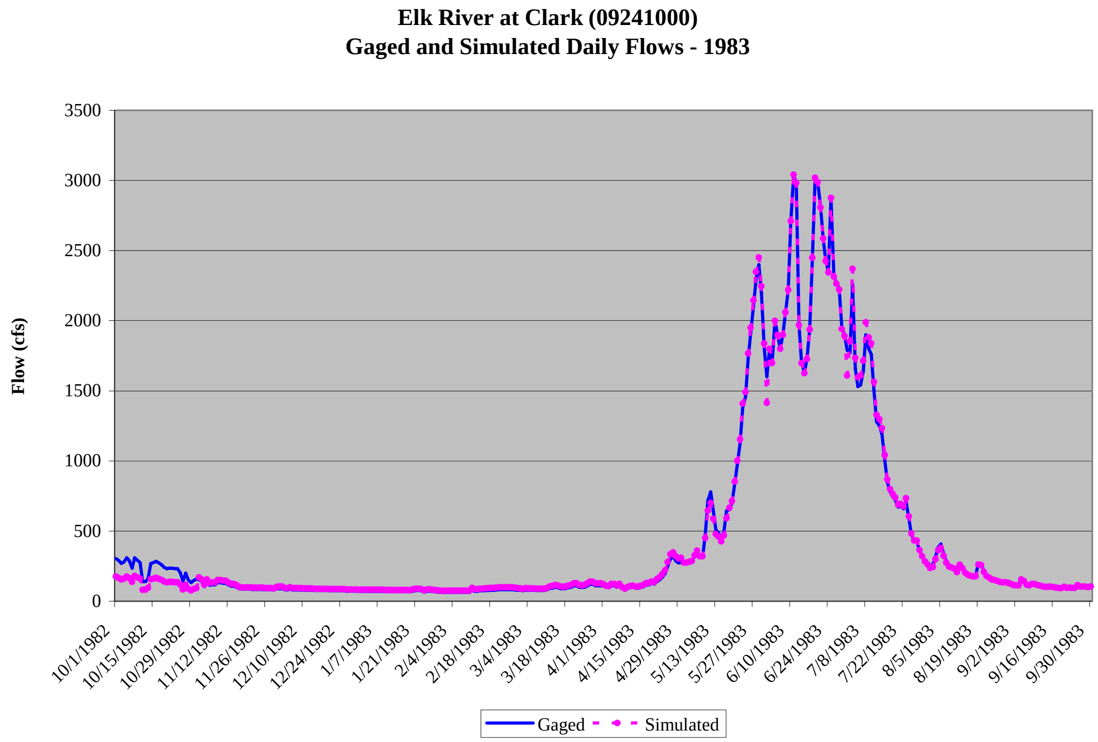


Figure F.4 Historical Daily Comparison, Wet Year – Elk River at Clark

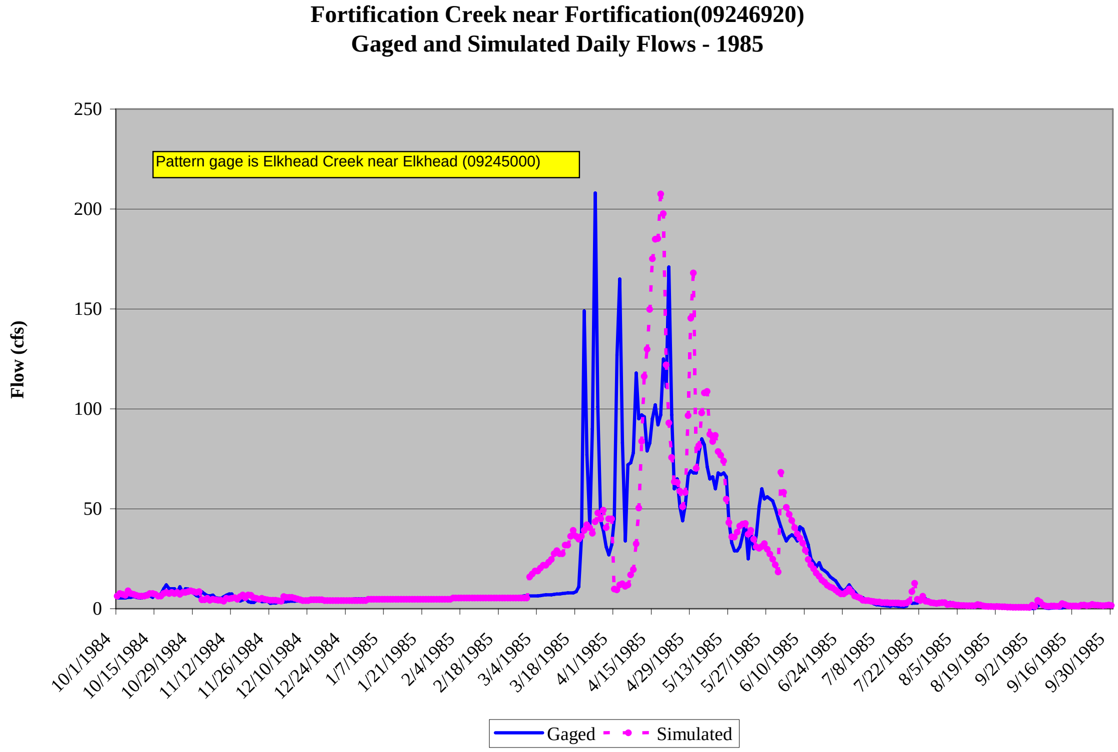


Figure F.5 Historical Daily Comparison, Wet Year – Fortification Creek near Fortification

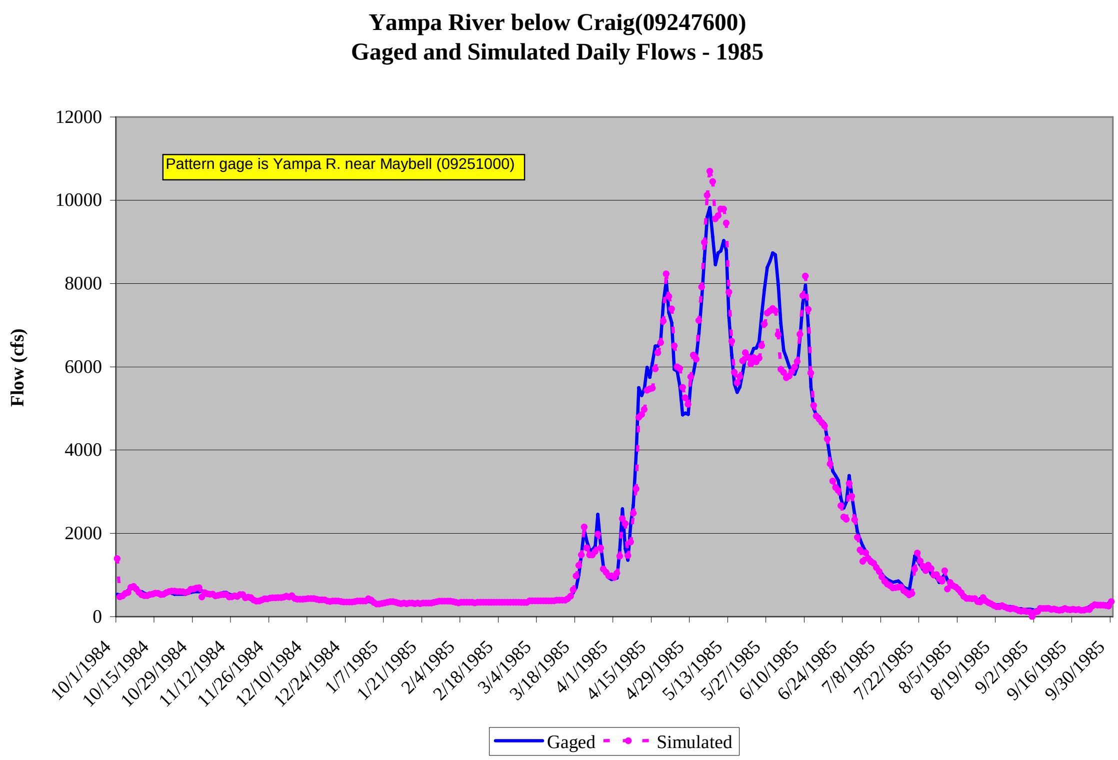


Figure F.6 Historical Daily Comparison, Wet Year – Yampa River below Craig

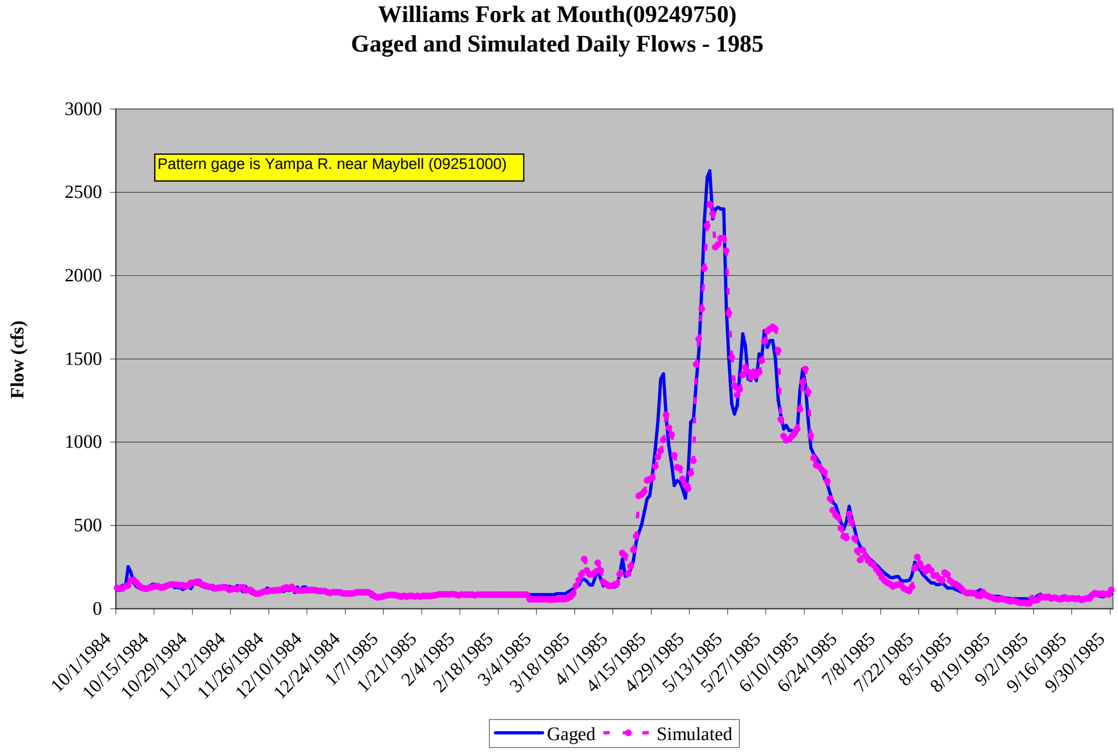


Figure F.7 Historical Daily Comparison, Wet Year – Williams Fork at Mouth

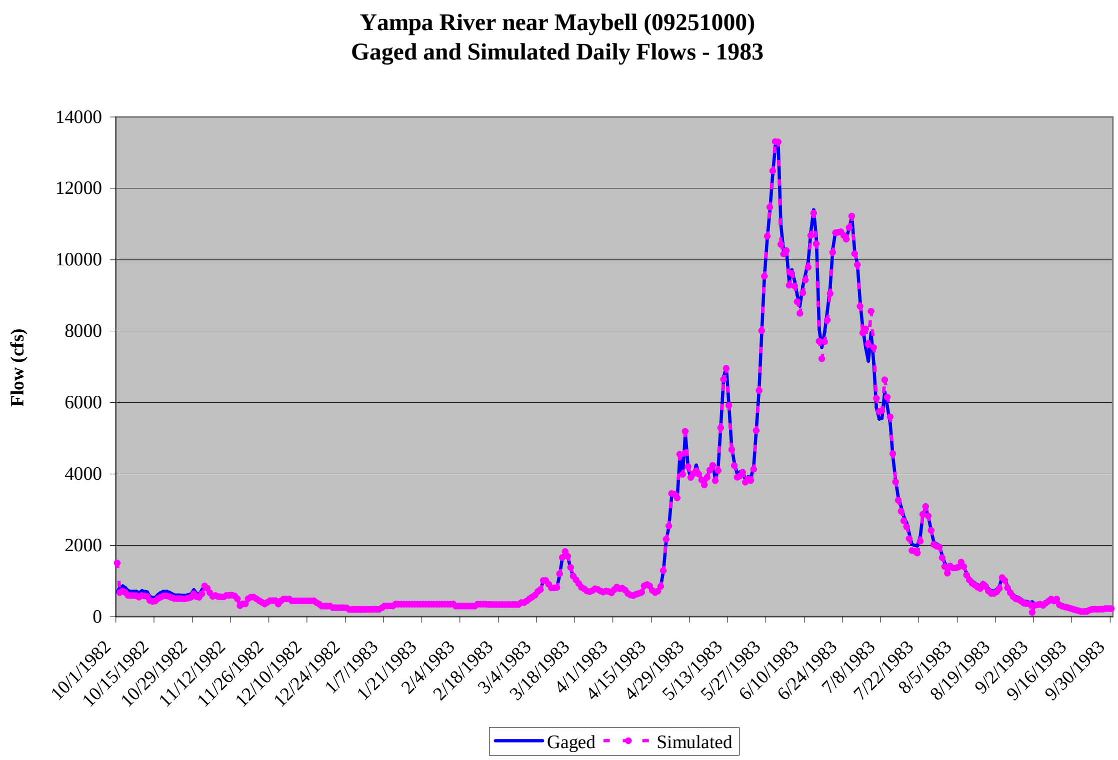


Figure F.8 Historical Daily Comparison, Wet Year – Yampa River near Maybell

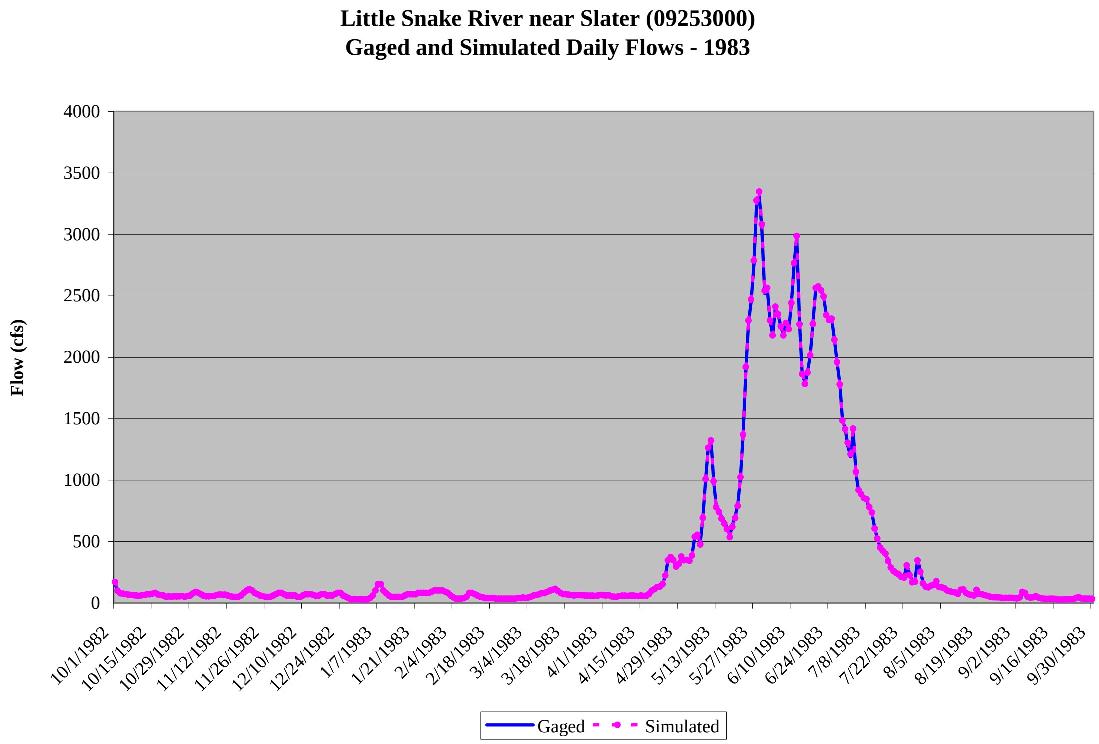


Figure F.9 Historical Daily Comparison, Wet Year – Little Snake River near Slater

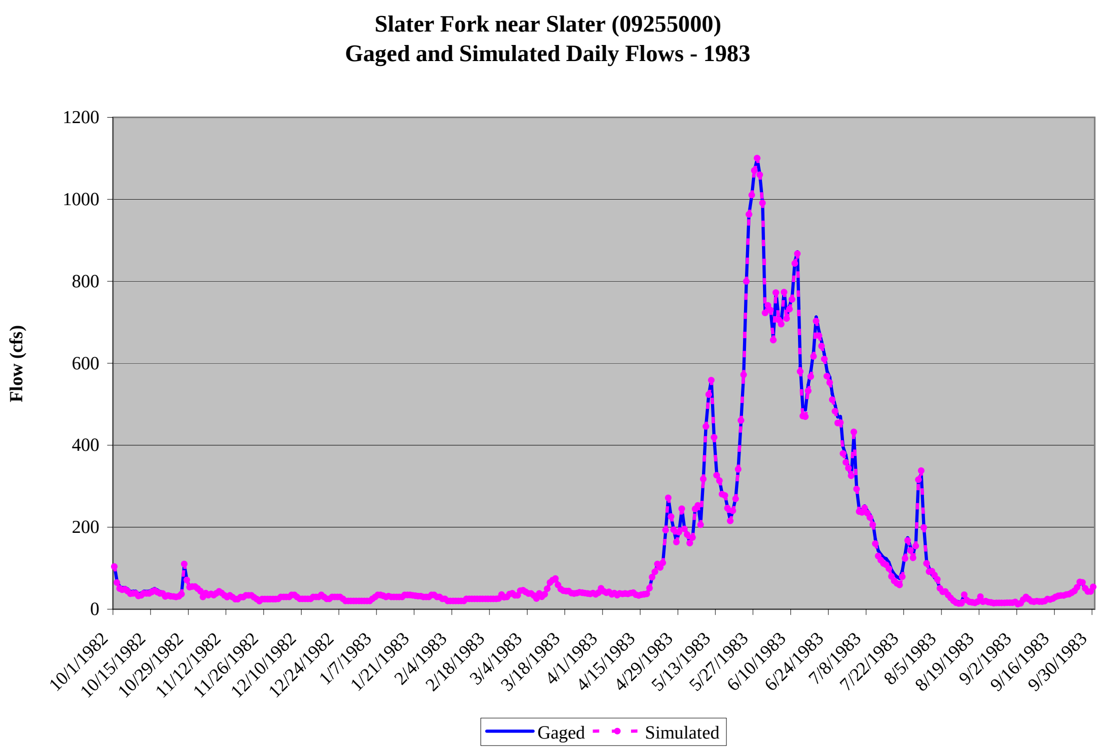


Figure F.10 Historical Daily Comparison, Wet Year – Slater Fork near Slater

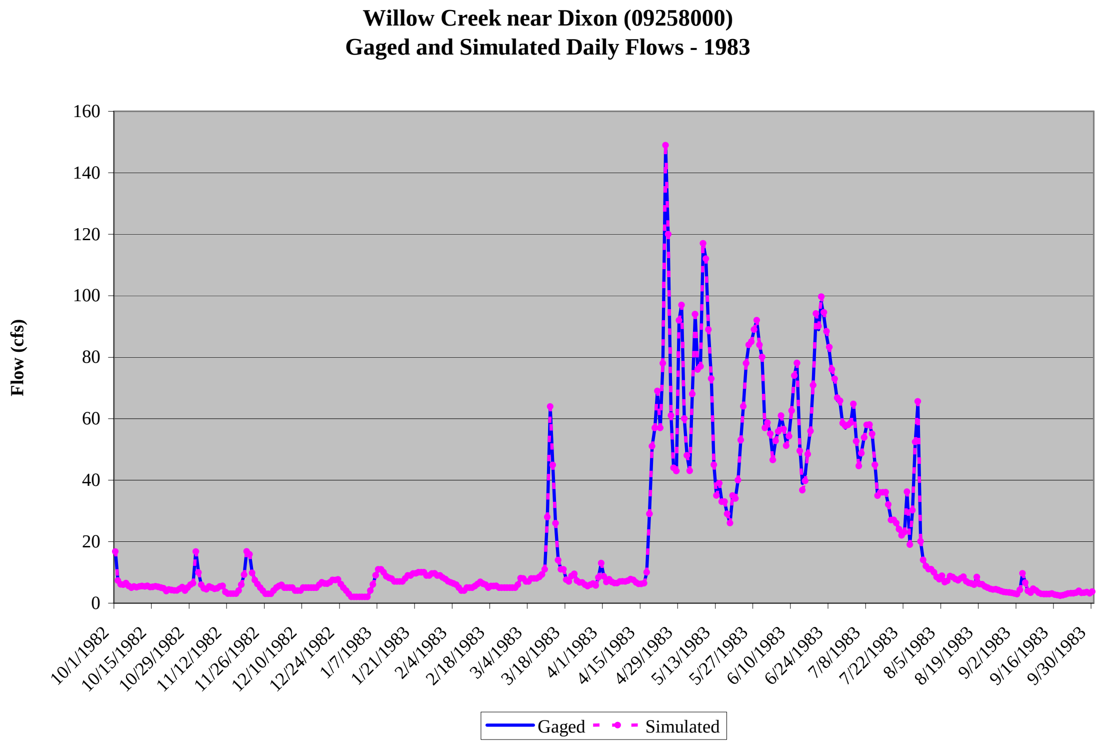


Figure F.11 Historical Daily Comparison, Wet Year – Willow Creek near Dixon

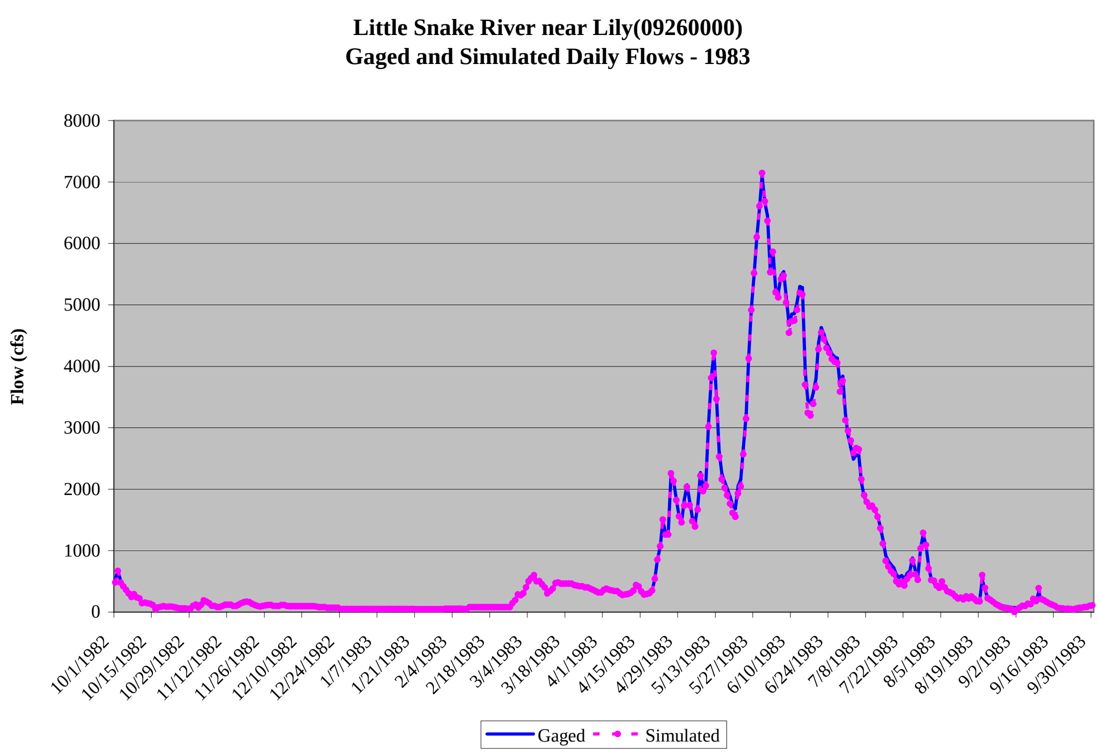


Figure F.12 Historical Daily Comparison, Wet Year – Little Snake River near Lily

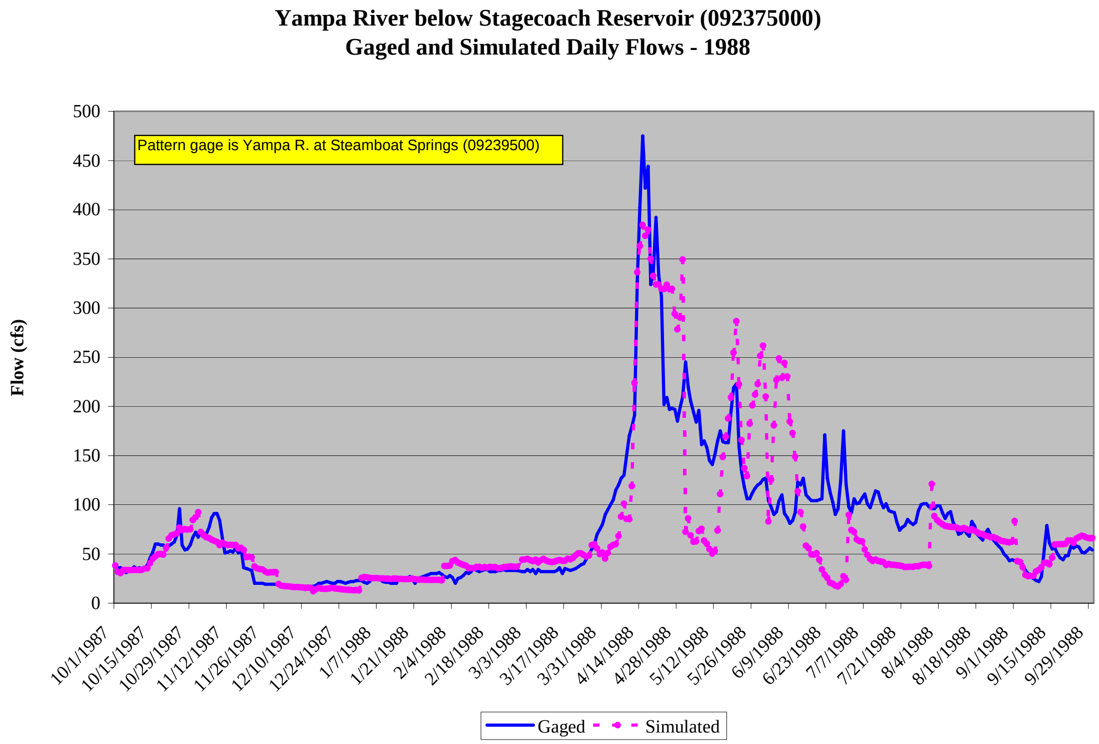


Figure F.13 Historical Daily Comparison, Average Year – Yampa River Below Stagecoach Reservoir

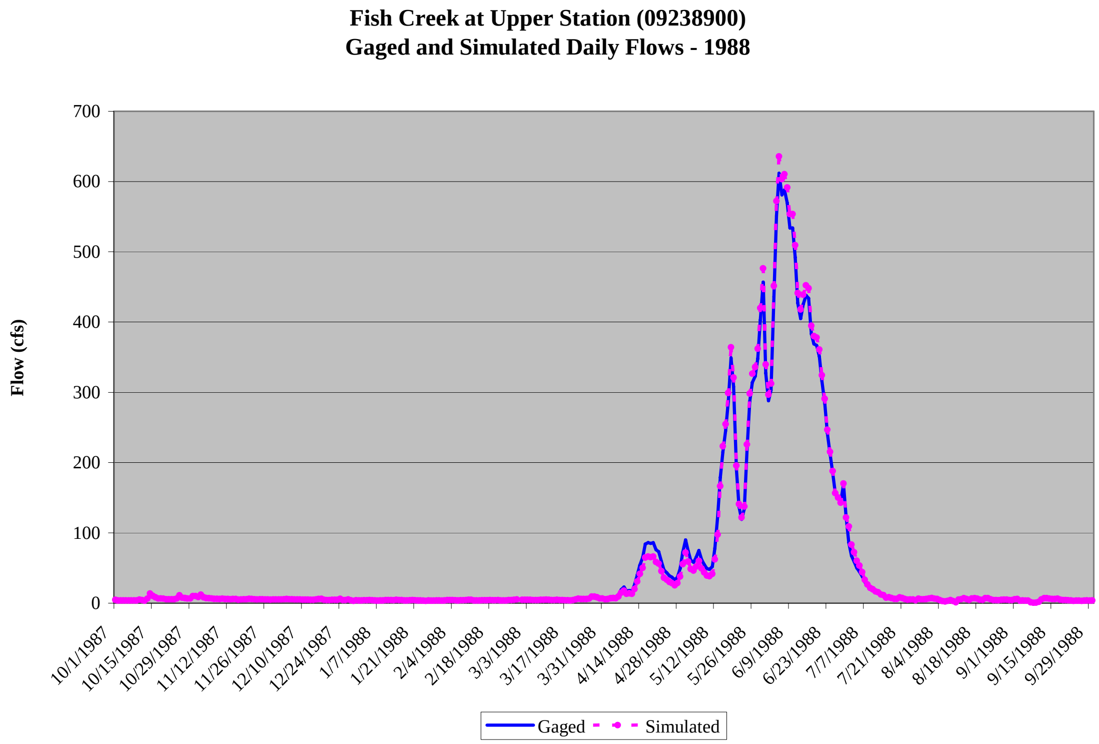


Figure F.14 Historical Daily Comparison, Average Year – Fish Creek at Upper Station

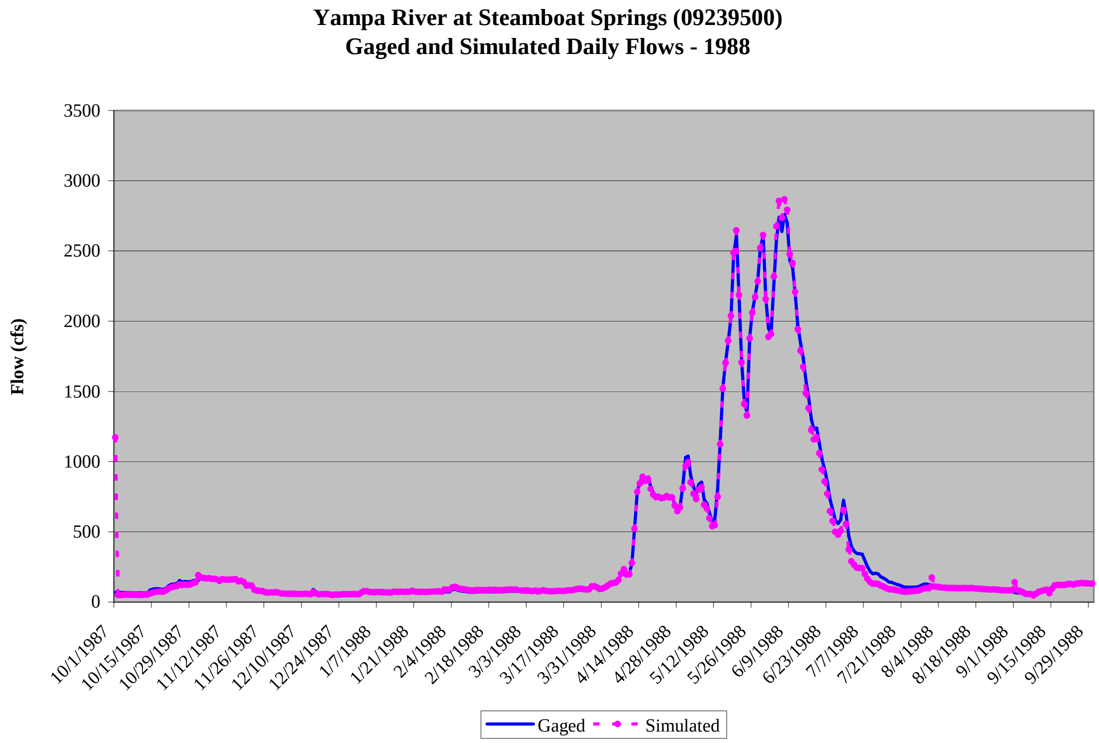


Figure F.15 Historical Daily Comparison, Average Year – Yampa River at Steamboat Springs

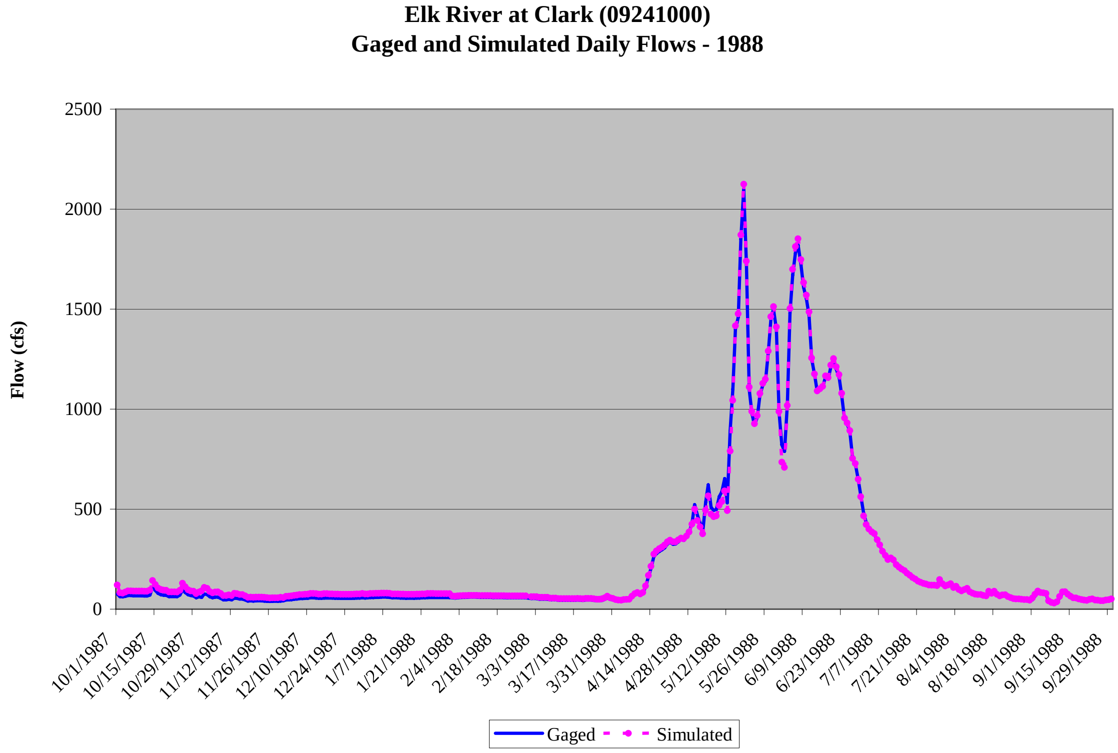


Figure F.16 Historical Daily Comparison, Average Year – Elk River at Clark

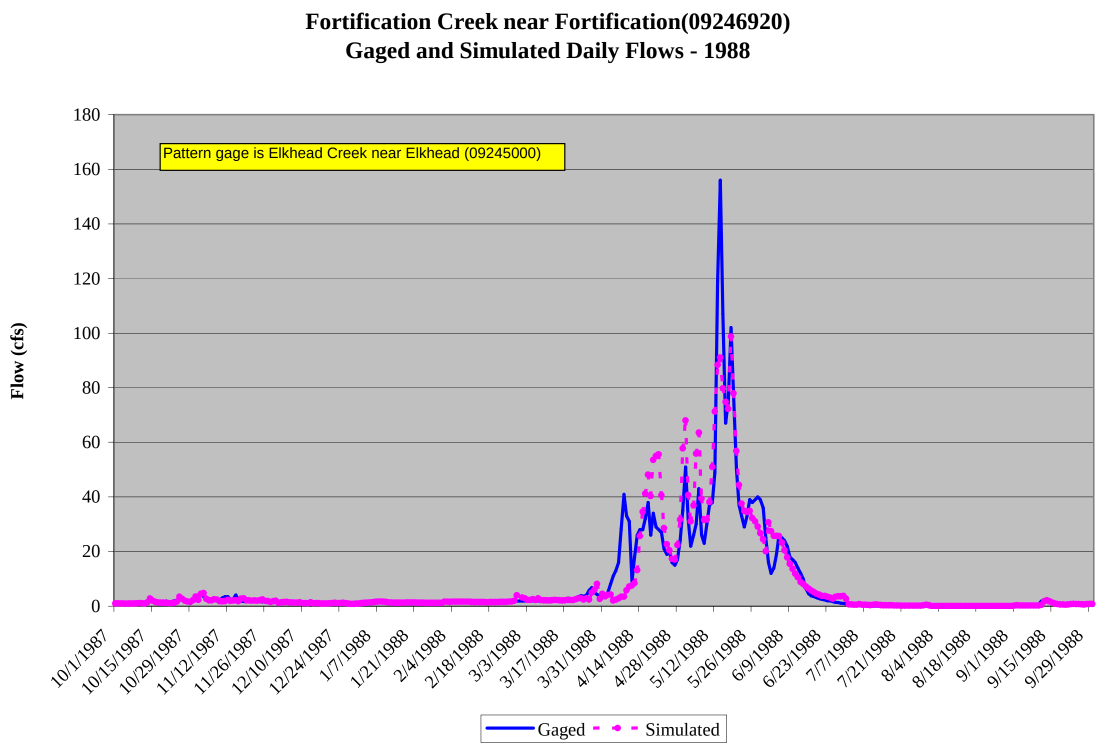


Figure F.17 Historical Daily Comparison, Average Year – Fortification Creek near Fortification

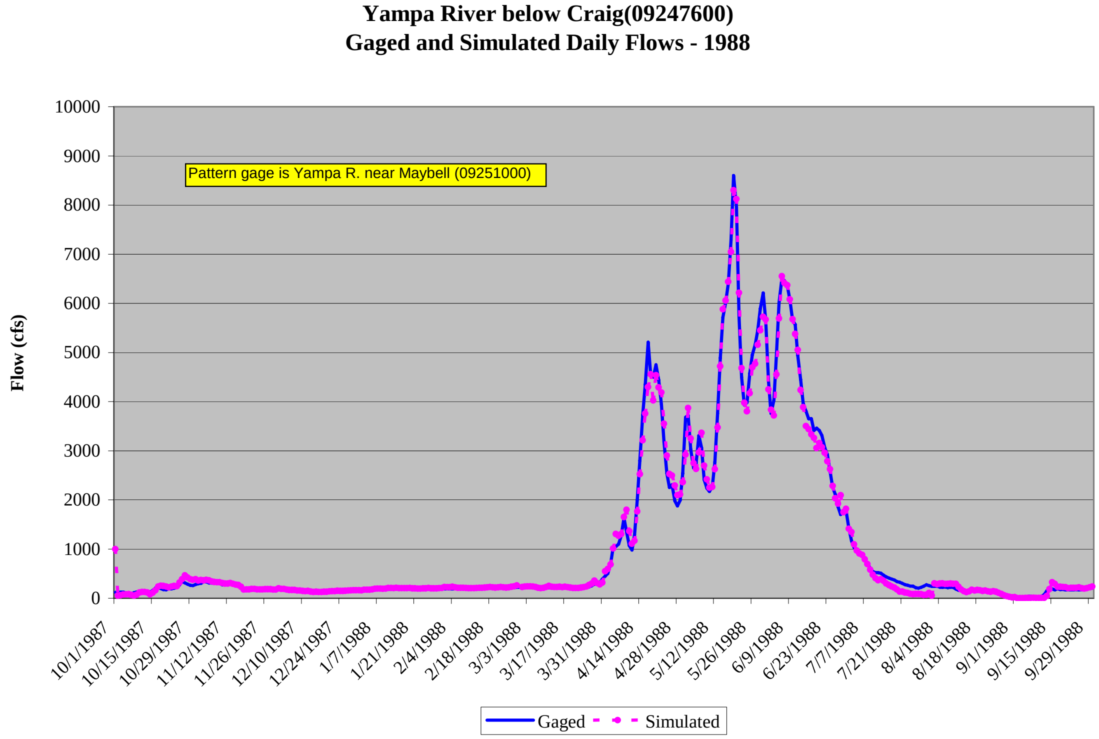


Figure F.18 Historical Daily Comparison, Average Year – Yampa River below Craig

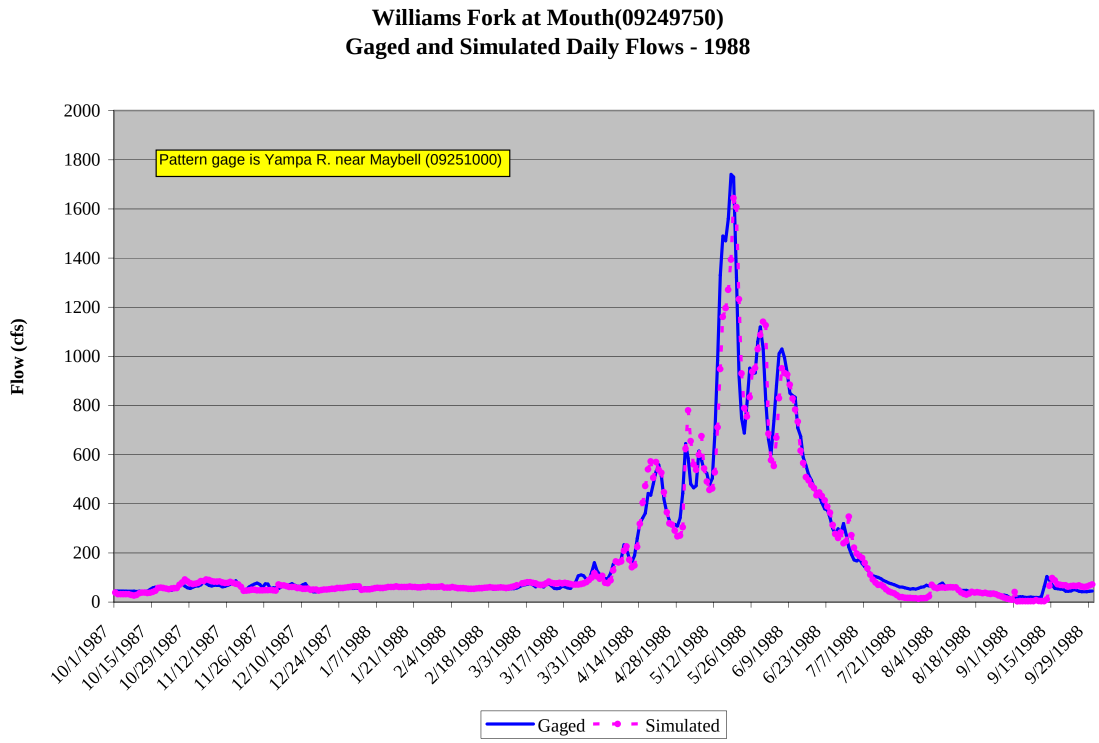


Figure F.19 Historical Daily Comparison, Average Year – Williams Fork at Mouth

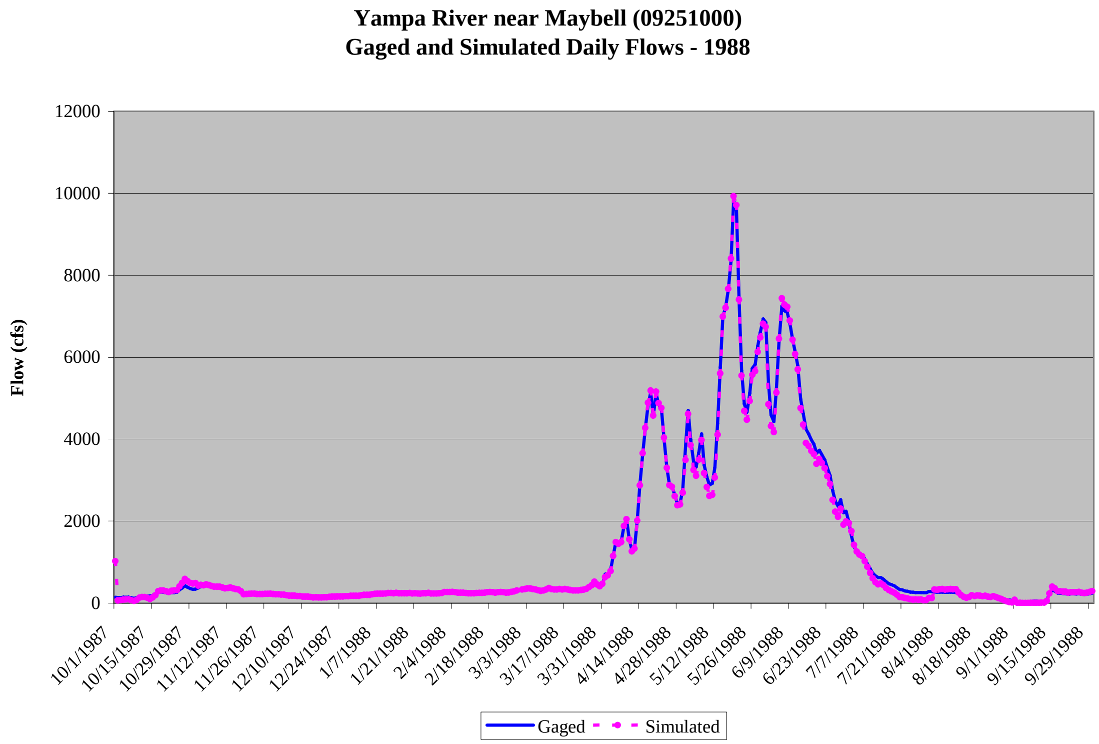


Figure F.20 Historical Daily Comparison, Average Year – Yampa River Near Maybell

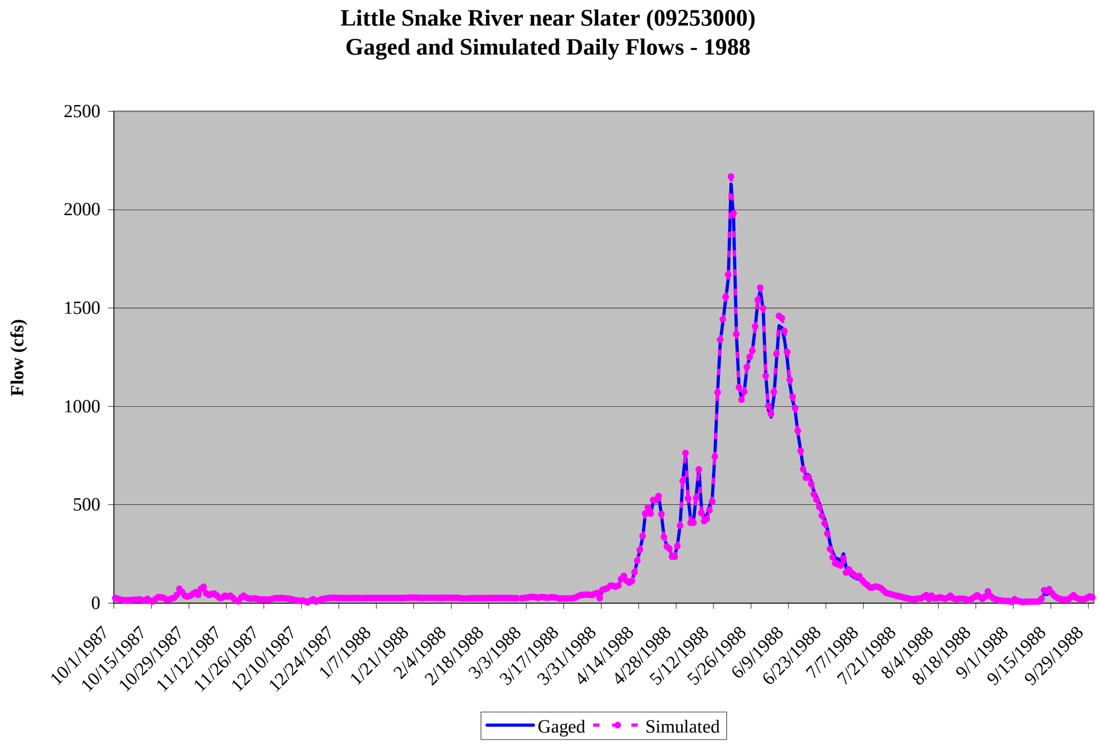


Figure F.21 Historical Daily Comparison, Average Year – Little Snake River near Slater

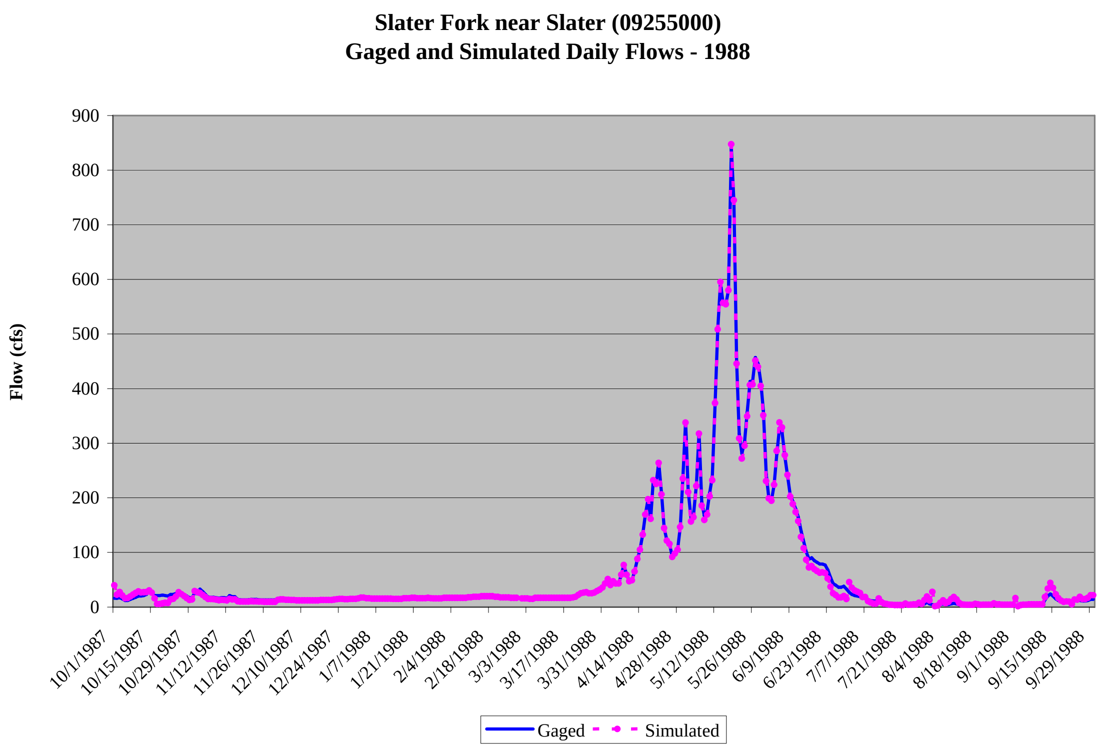


Figure F.22 Historical Daily Comparison, Average Year – Slater Fork near Slater

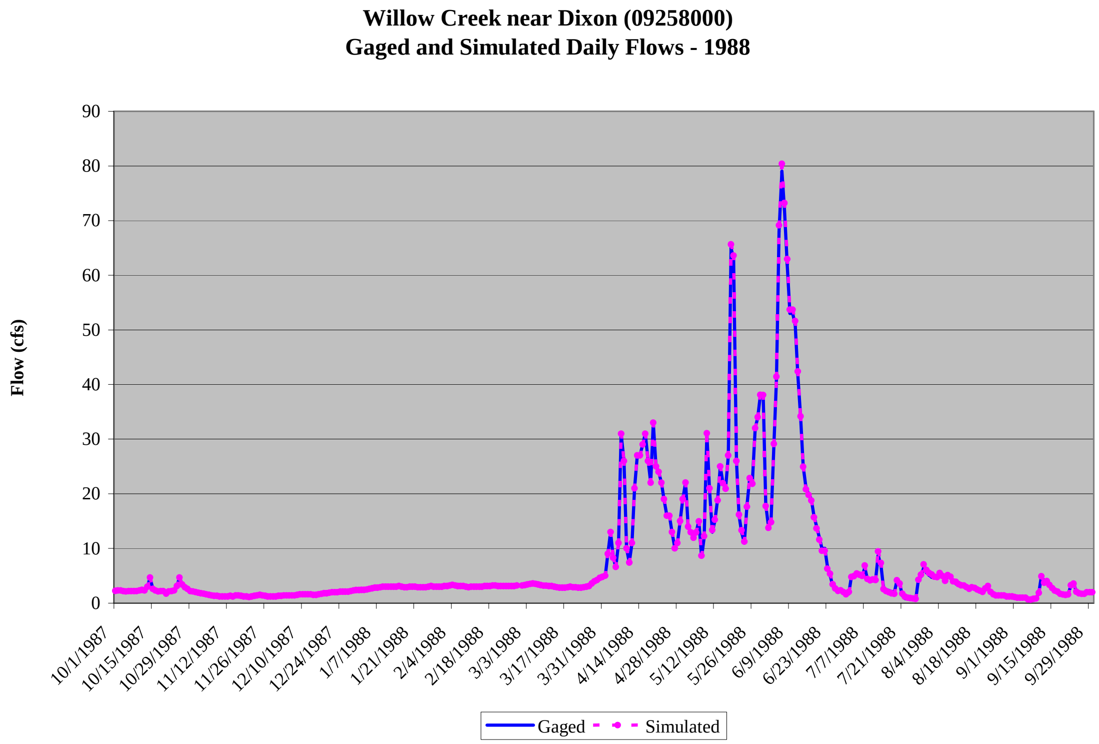


Figure F.23 Historical Daily Comparison, Average Year – Willow Creek Near Dixon

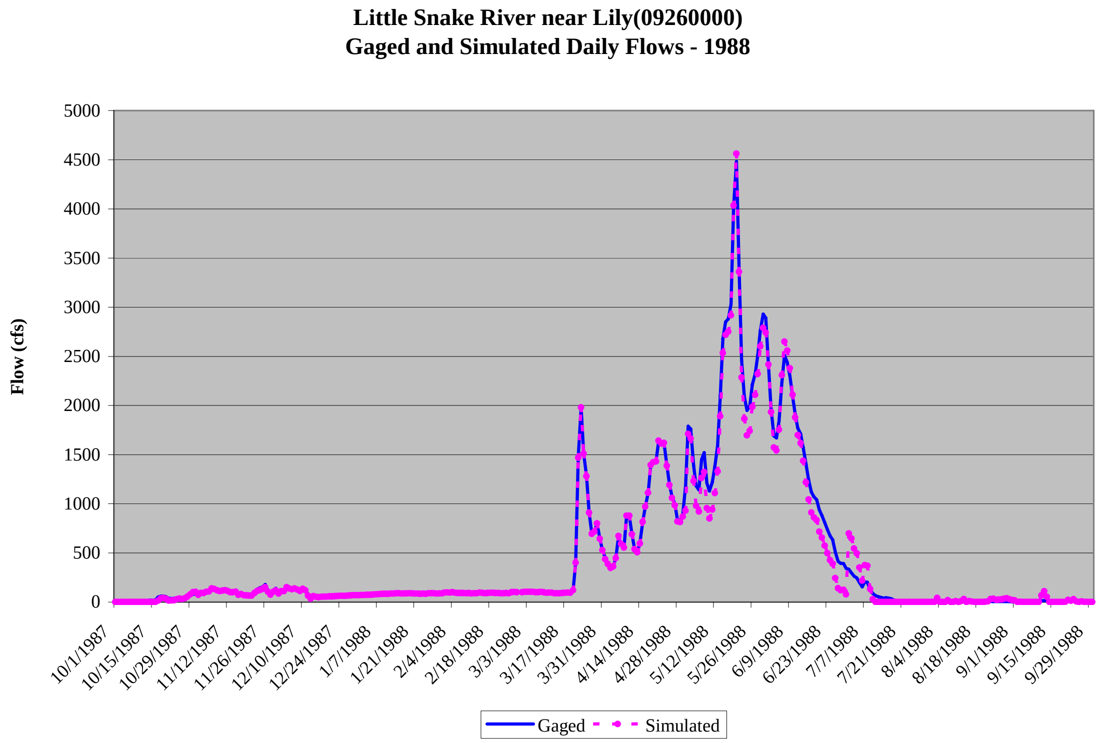


Figure F.24 Historical Daily Comparison, Average Year – Little Snake River near Lilly

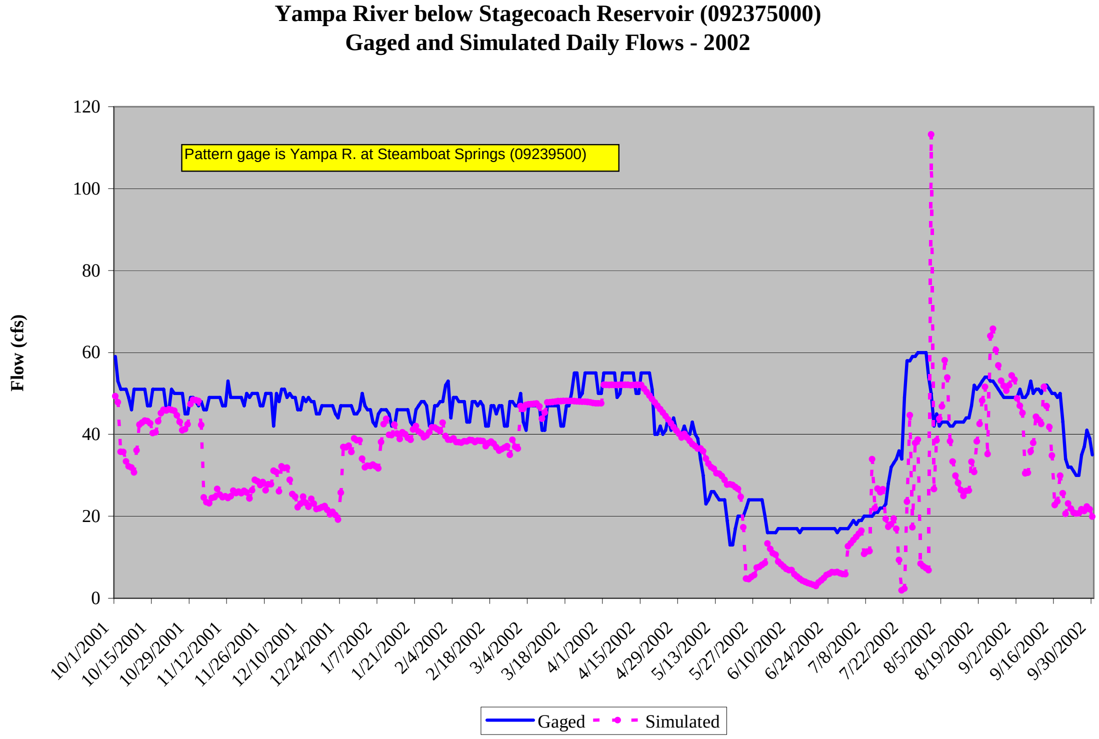


Figure F.25 Historical Daily Comparison, Dry Year – Yampa River below Stagecoach Reservoir

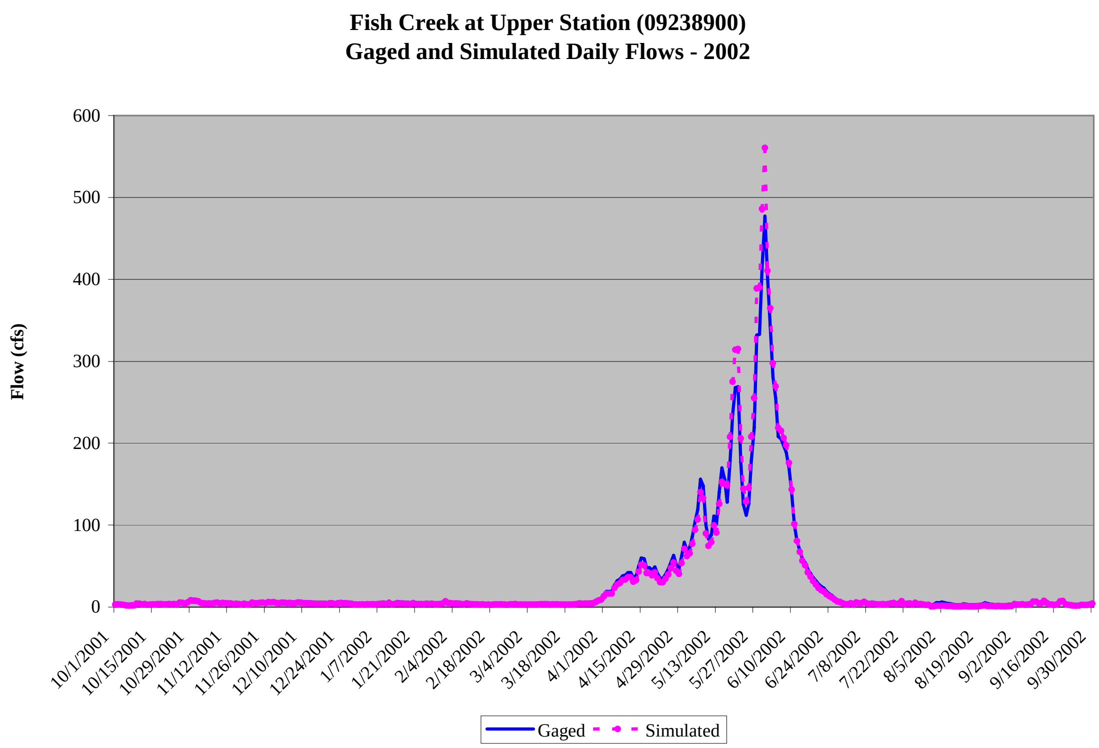


Figure F.26 Historical Daily Comparison, Dry Year – Fish Creek at Upper Station

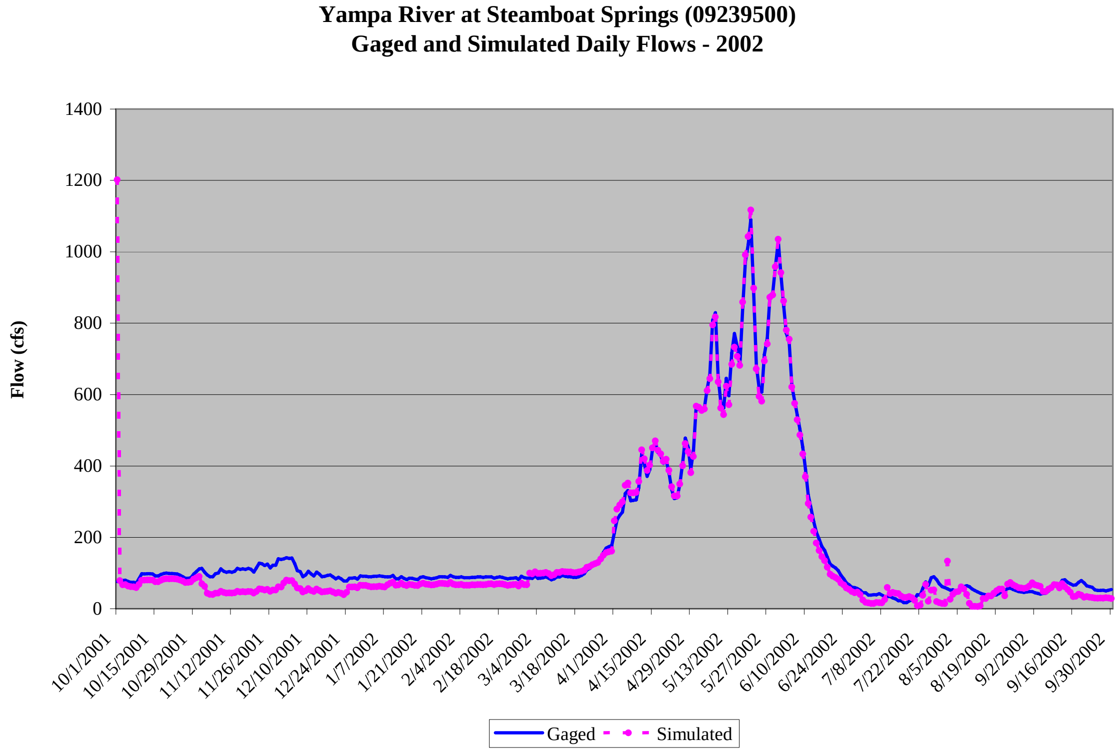


Figure F.27 Historical Daily Comparison, Dry Year – Yampa River at Steamboat Springs

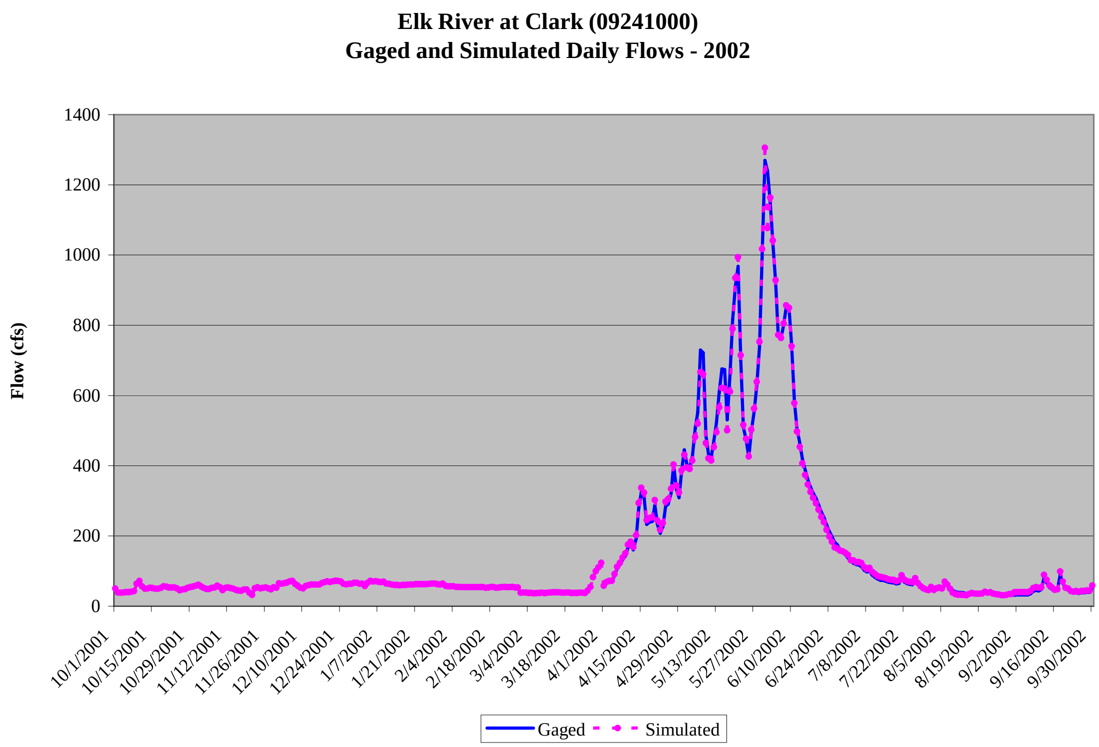


Figure F.28 Historical Daily Comparison, Dry Year – Elk River at Clark

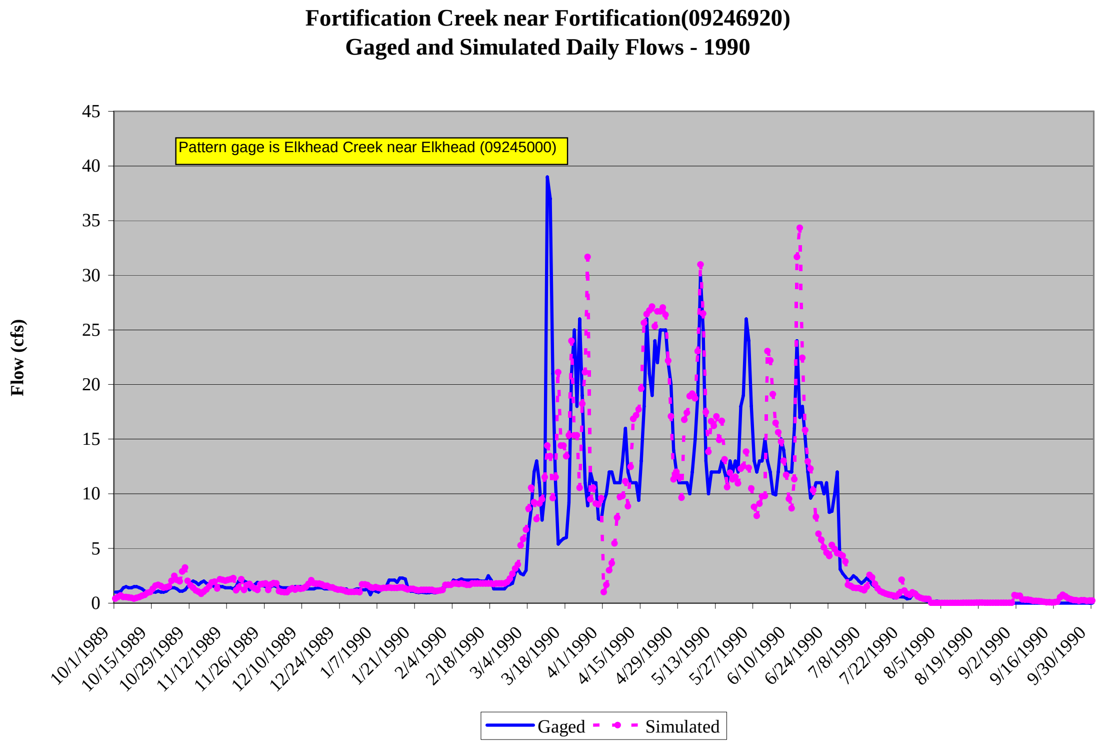


Figure F.29 Historical Daily Comparison, Dry Year – Fortification Creek near Fortification

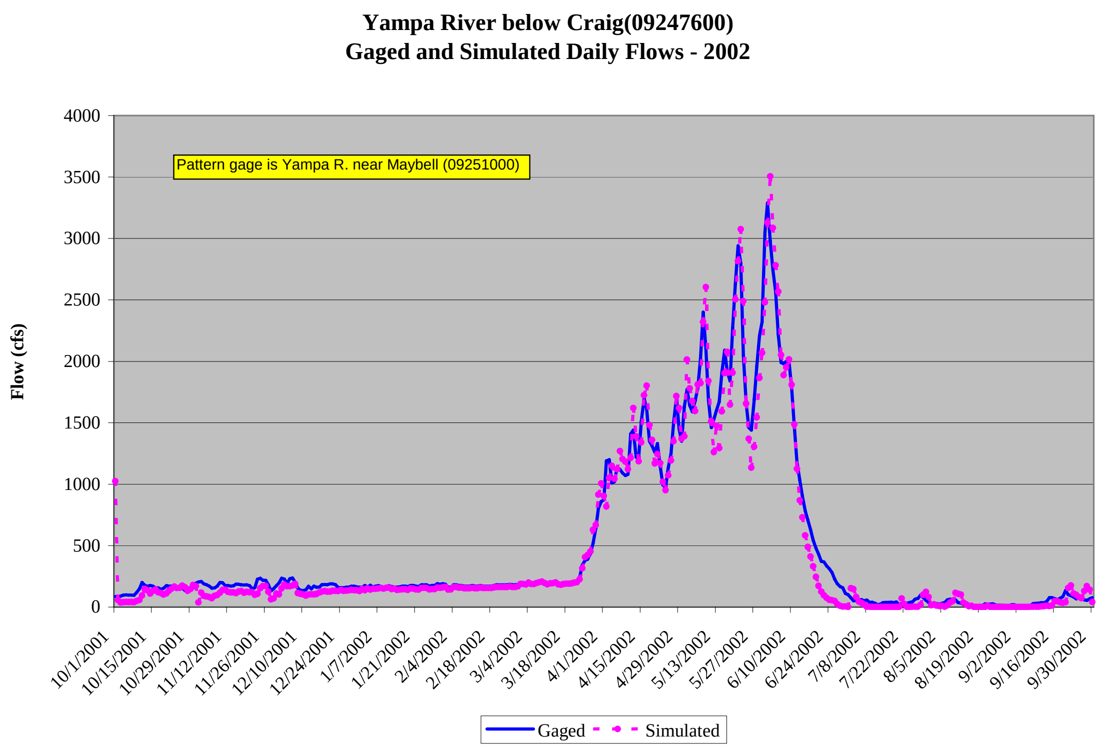


Figure F.30 Historical Daily Comparison, Dry Year – Yampa River Below Craig

Williams Fork at Mouth(09249750)
Gaged and Simulated Daily Flows - 1990

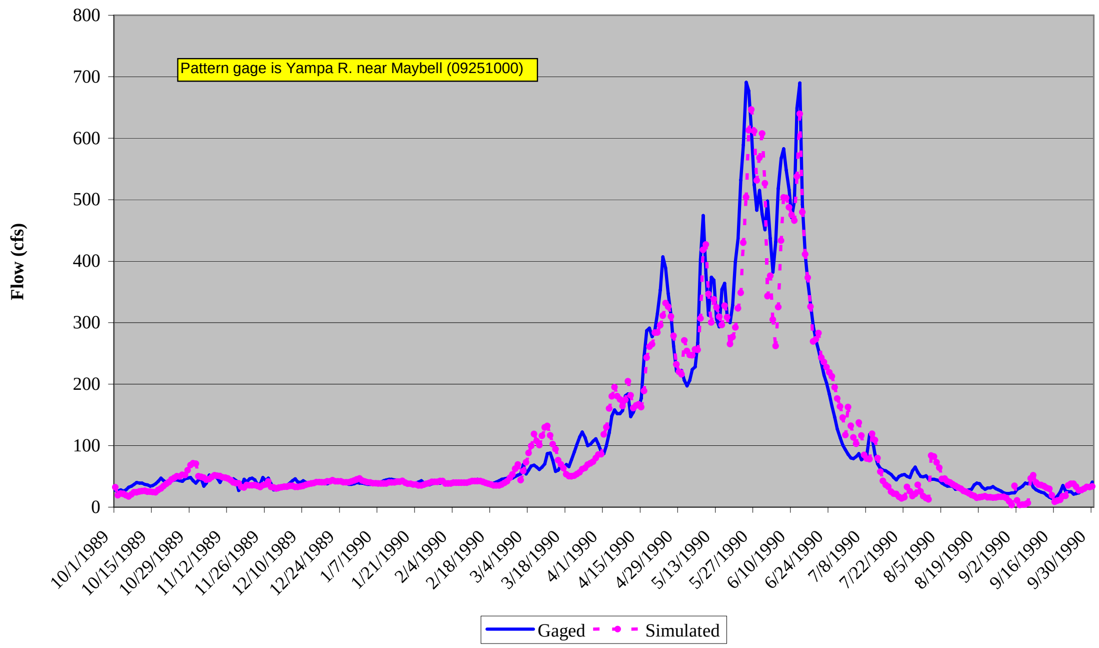


Figure F.31 Historical Daily Comparison, Dry Year – Williams Fork at Mouth

Yampa River near Maybell (09251000)
Gaged and Simulated Daily Flows - 2002

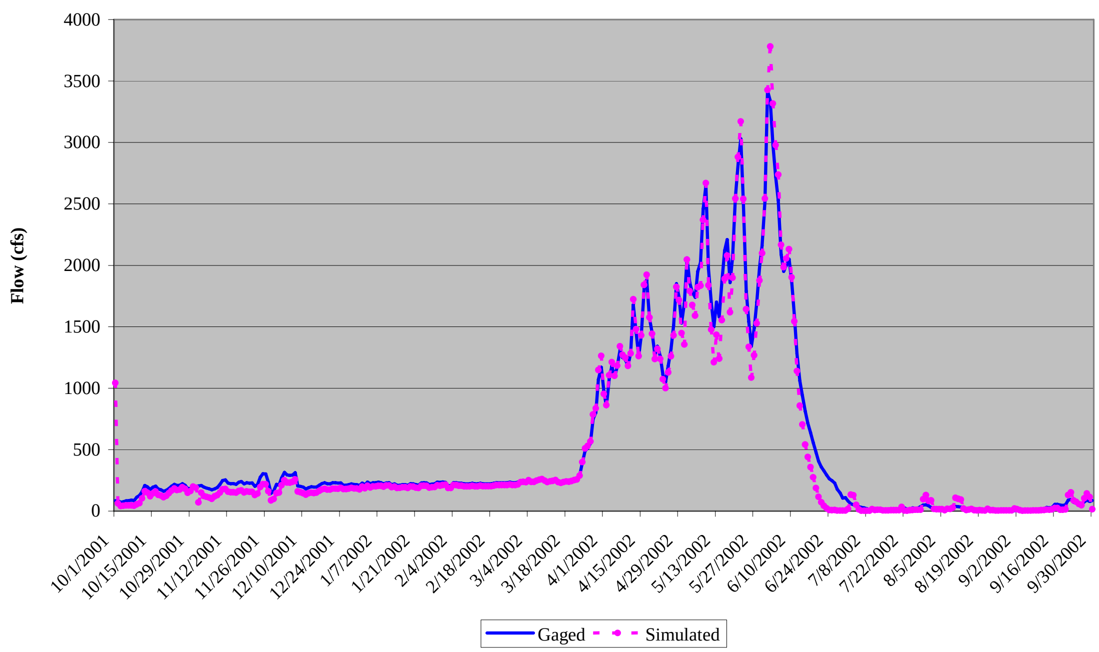


Figure F.32 Historical Daily Comparison, Dry Year – Yampa River near Maybell

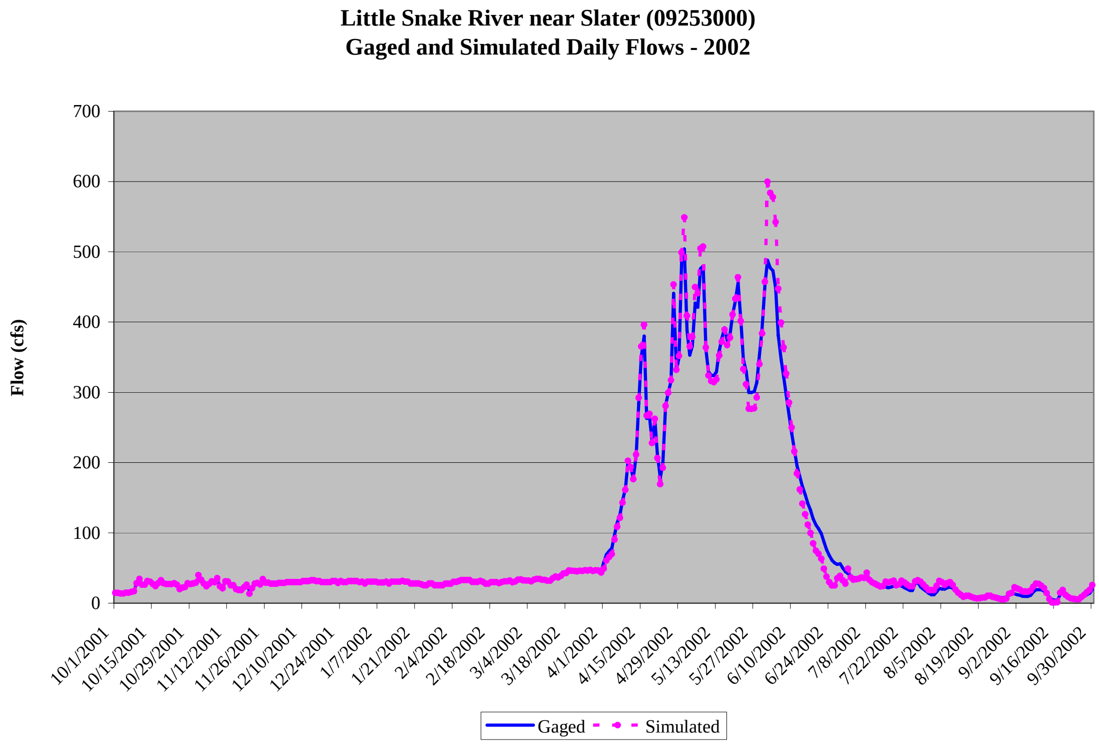


Figure F.33 Historical Daily Comparison, Dry Year – Little Snake River near Slater

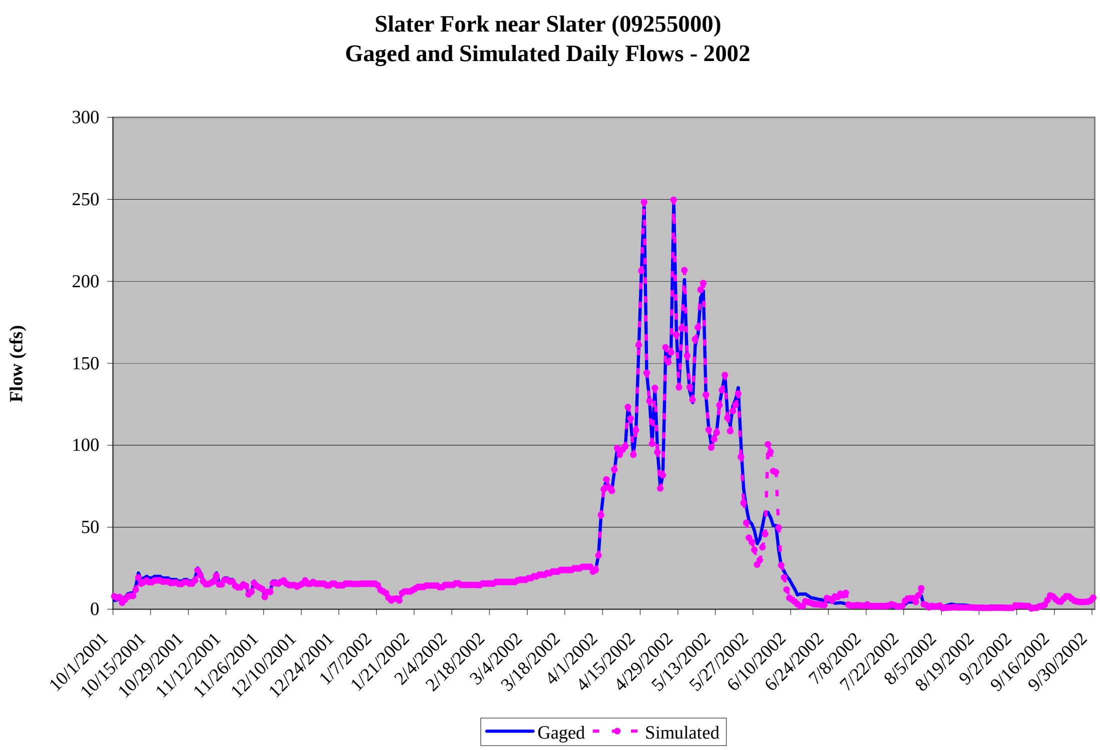


Figure F.34 Historical Daily Comparison, Dry Year – Slater Fork near Slater

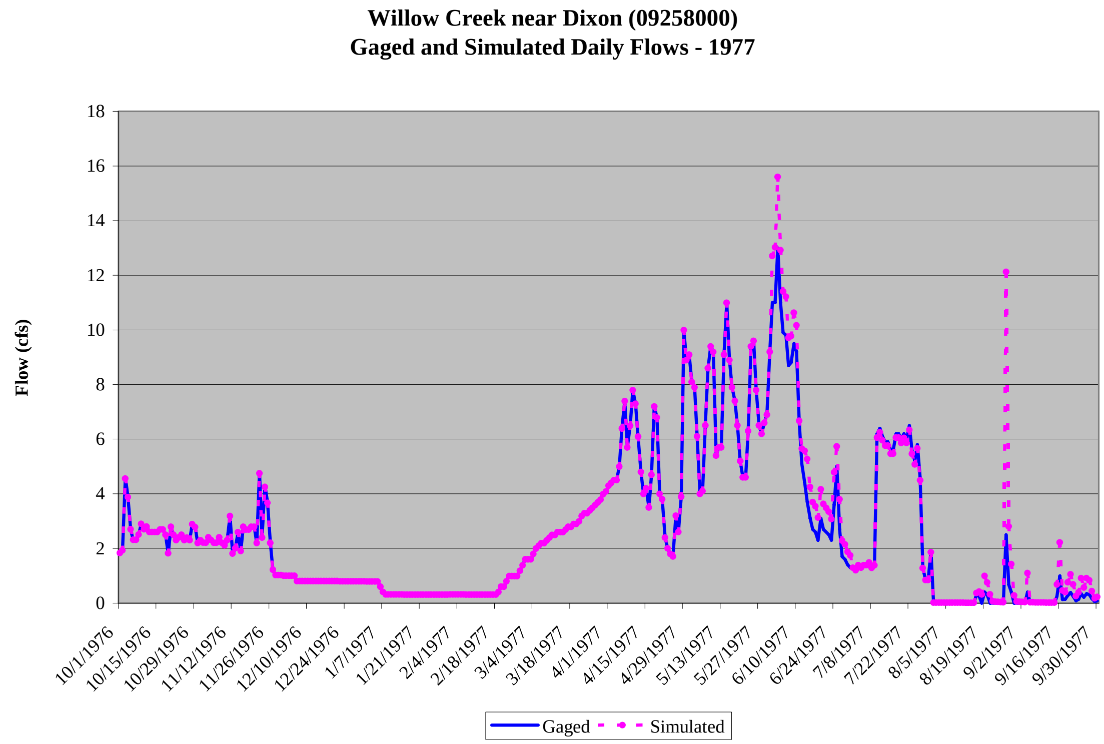


Figure F.35 Historical Daily Comparison, Dry Year – Willow Creek near Dixon

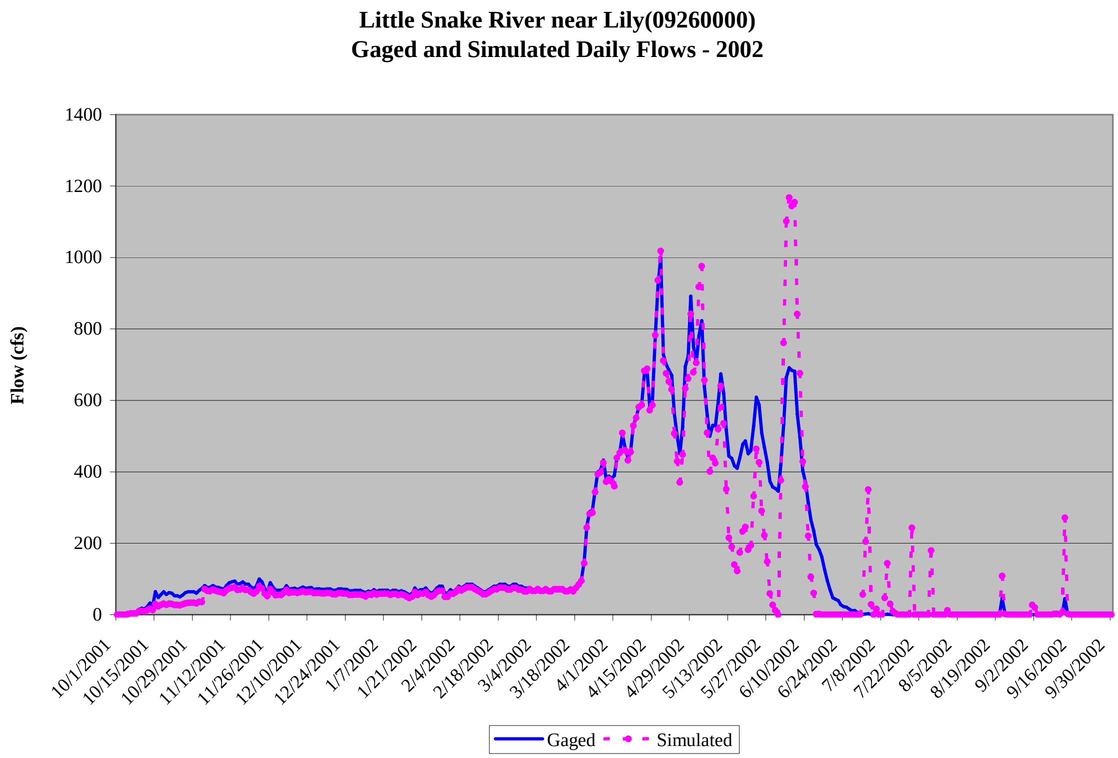


Figure F.36 Historical Daily Comparison, Dry Year – Little Snake River near Lily

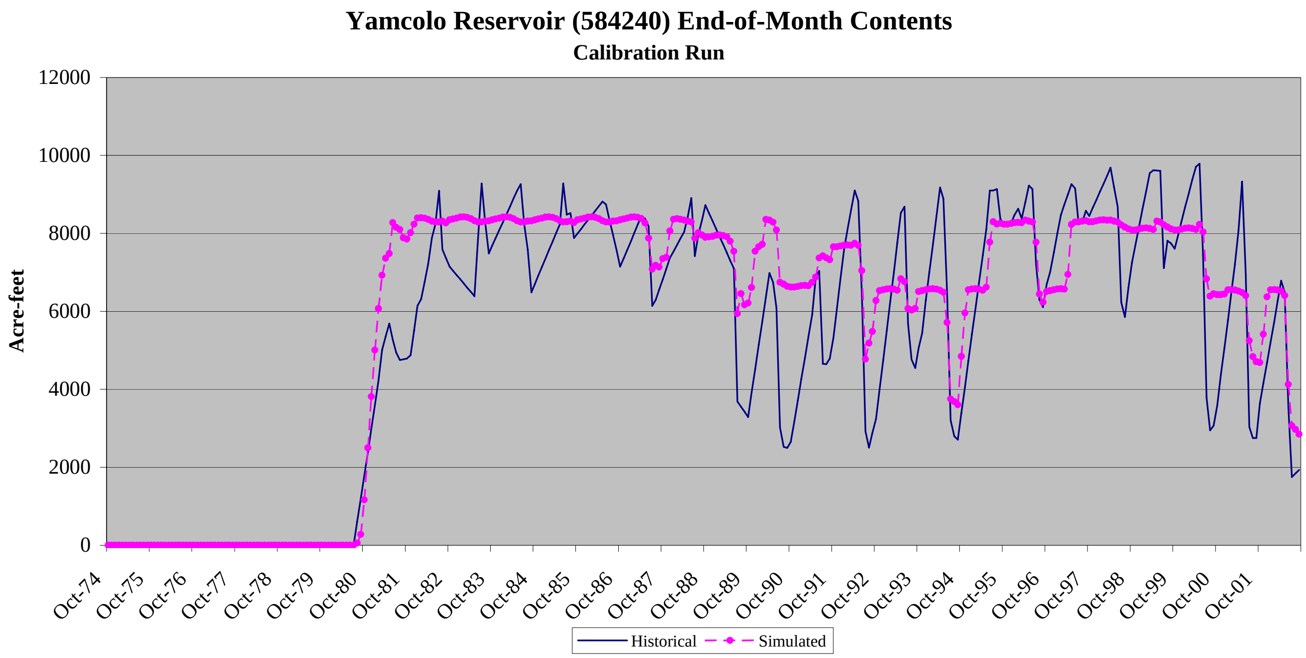


Figure F.37 Historical Daily Reservoir Simulation – Yamcolo Reservoir

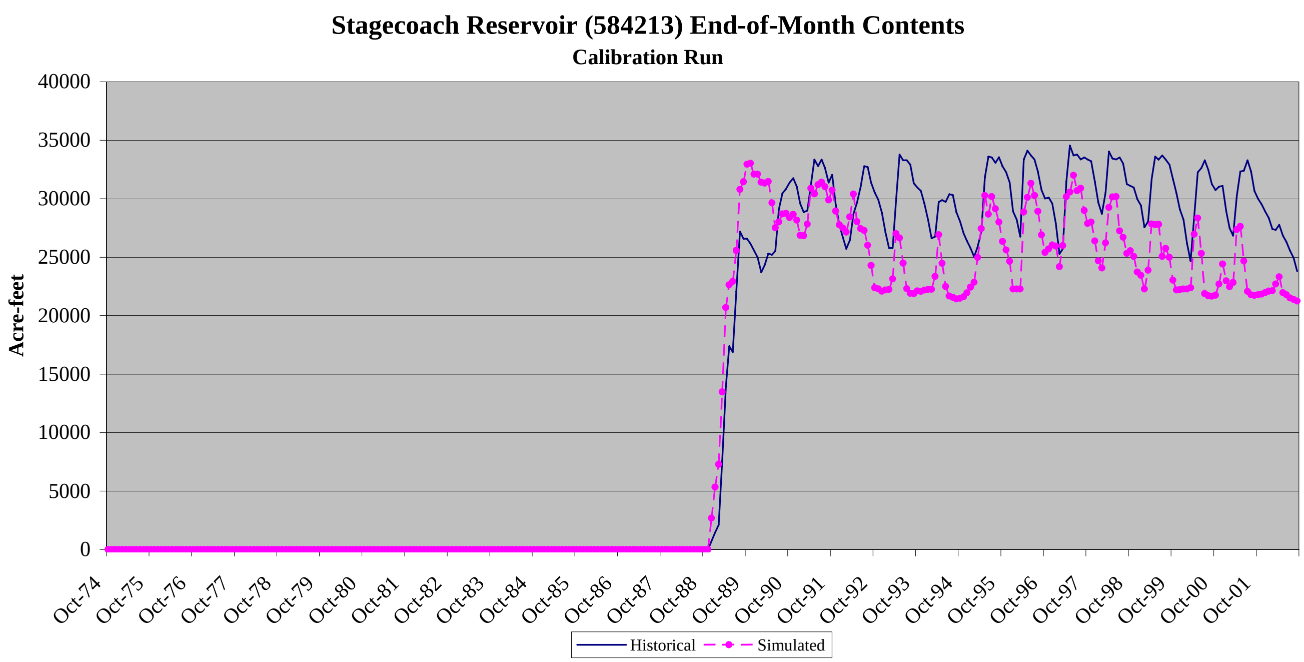


Figure F.38 Historical Daily Reservoir Simulation – Stagecoach Reservoir

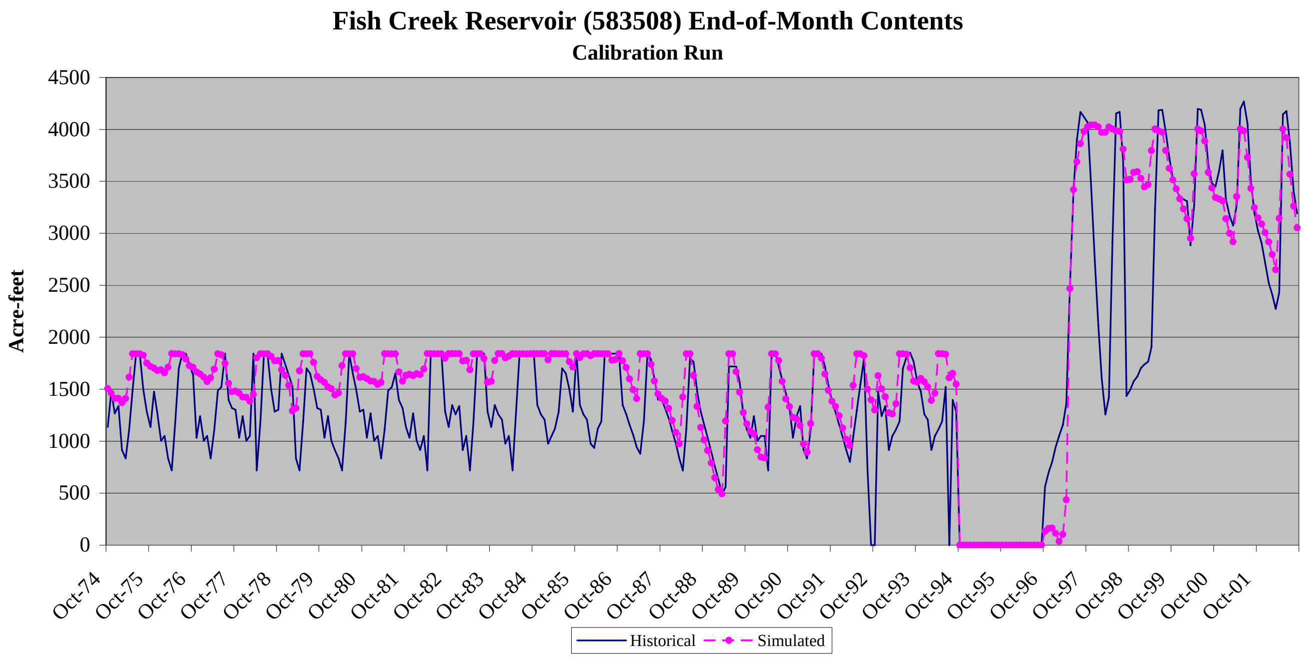


Figure F.39 Historical Daily Reservoir Simulation – Fish Creek Reservoir

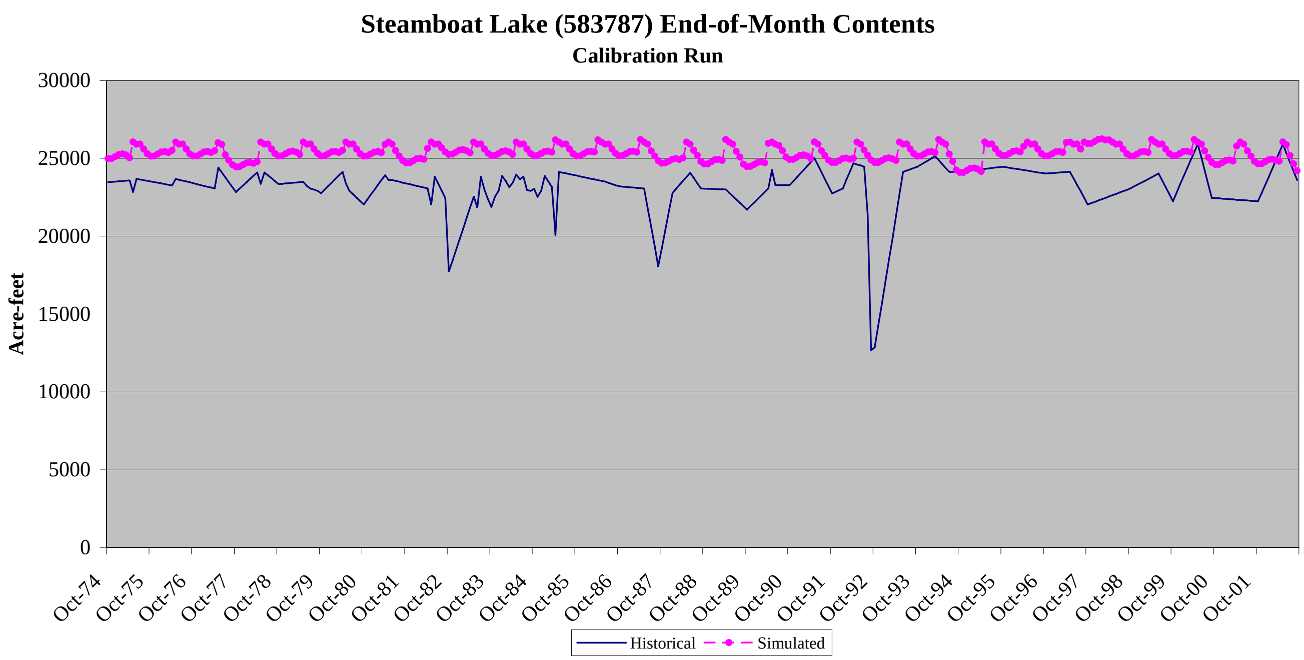


Figure F.40 Historical Daily Reservoir Simulation – Steamboat Lake

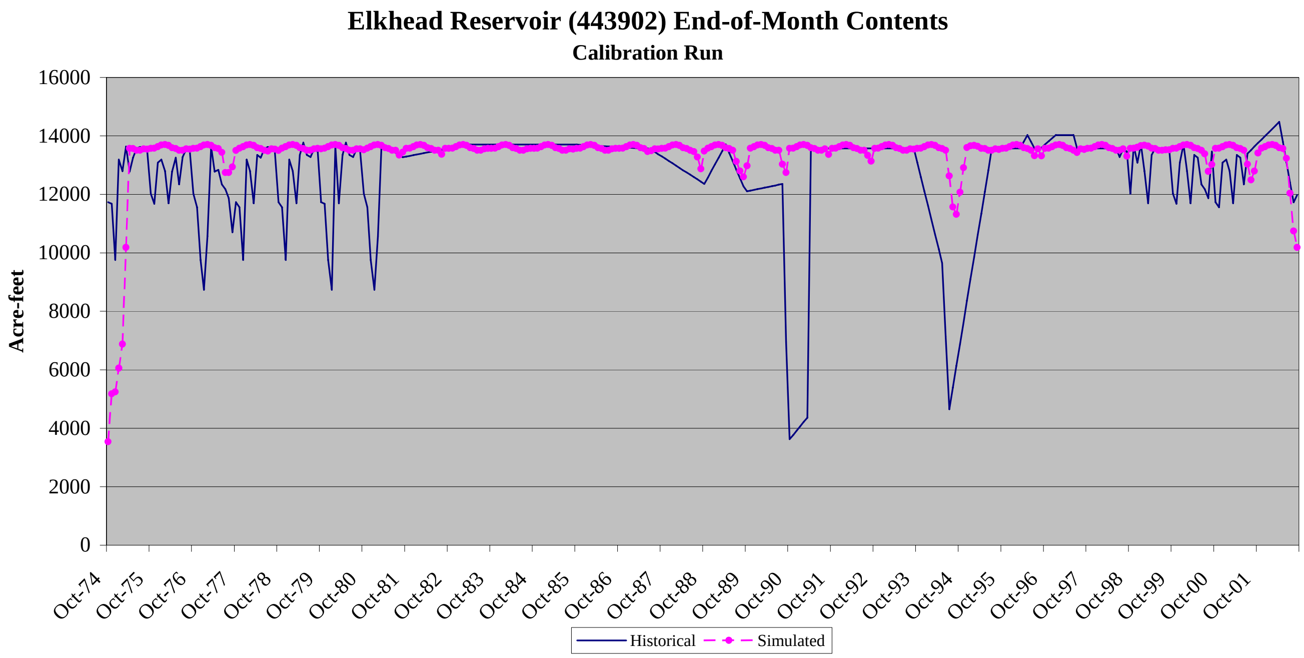


Figure F.41 Historical Daily Reservoir Simulation – Elkhead Reservoir